INDEX

TO THE

EXECUTIVE DOCUMENTS

OF THE

HOUSE OF REPRESENTATIVES

FOR THE

SECOND SESSION OF THE FORTY-FIFTH CONGRESS,

1877-'78.

IN 22 VOLUMES.

VOLUME IV.—Report of the Chief of Engineers (No. 1, Pt. 2. Vol. 2), Pt. 2.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1878.

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REPORT

OF THE

SECRETARY OF WAR;

BEING PART OF

THE MESSAGE AND DOCUMENTS

COMMUNICATED TO THE

TWO HOUSES OF CONGRESS

AT THE

BEGINNING OF THE SECOND SESSION OF THE FORTY-FIFTH CONGRESS.

VOLUME II.

PART II.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1877.

APPENDIX X.

ANNUAL REPORT OF MAJOR F. U. FARQUHAR, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

(Letter of transmittal under Appendix Q.)

X 1.

IMPROVEMENT OF DULUTH HARBOR, MINNESOTA.

Three hundred and ten and a half cords of stone were placed as an enrockment along the channel-face of the north pier, where it had been undermined by the current. Since then no further settlement has been observed. The pier was not repaired, as it was deemed better to wait for a year to see whether any further settlement would take place. As it was in September before the work could commence, there was no time to advertise for proposals for furnishing stone, so that it was purchased in open market at the low rate of $4.90 per cord, delivered and put in place. Of the amount allotted last September for the repairs of the north pier, there remains $3,850, which it is proposed to hold in reserve for that purpose.

Of the appropriation made by act approved March 3, 1875, which is only applicable for dredging in the inside harbor, there remains $3,868.34, with which, and the $9,000 available from the appropriation made by act approved August 14, 1876, it is proposed to continue the dredging in the inside harbor, and in dredging a channel through the bar formed on the north side and opposite to the cut in the dike—this latter requiring about 3,300 cubic yards to be dredged. Proposals have been received and a contract awarded for this work to Messrs. Williams & Upham. It is hoped that for the amount available about 60,000 cubic yards can be dredged from the inside harbor in continuation of former dredging.

The original estimate for dredging over the inside harbor was $269,739.25. There has been appropriated or allotted for this dredging $55,446.07, leaving $214,293.18 still to be appropriated. If this work is to be continued, I think that at least $50,000 should be appropriated annually, so that it could give work for at least two dredges.

Duluth is in the collection-district of Duluth.

The total amount of the duties collected in the district of Duluth during the year was $565.71.

Money statement.

July 1, 1876, amount available	$4,317 06	
Amount appropriated by act approved August 14, 1876	15,000 00	
		$19,317 06
July 1, 1877, amount expended during fiscal year	2,601 35	
July 1, 1877, outstanding liabilities	32 12	
		2,633 47
July 1, 1877, amount available		16,683 59
Amount (estimated) required for completion of existing project		214,293 18
Amount that can be profitably expended in fiscal year ending June 30, 1879		50,000 00

Abstract of appropriations made for the harbor of Duluth, and how expended or to be expended

	Construction of breakwater.	Repairs of piers &c.	Dredging inside harbor.	Total.
Appropriation approved March 3, 1871	$60,000 00			$60,000 00
Appropriation approved June 10, 1872	50,000 00			50,000 00
Allotted from appropriation approved March 3, 1873		$32,723 59	$3,325 61	36,049 20
Appropriation approved June 23, 1874		1,879 54	8,120 46	10,000 00
Appropriation approved March 3, 1875			35,000 00	35,000 00
Appropriation approved August 14, 1876		6,000 00	9,000 00	15,000 00
Totals	110,000 00	40,603 13	55,446 07	206,049 20

Original estimate for dredging inside harbor	$269,739 25
Remaining to be appropriated	214,293 18

Abstract of proposals for dredging the inside harbor of Duluth, Minnesota, opened June 29, 1877, by Major F. U. Farquhar, Corps of Engineers, U. S. A.

Name and residence of bidders.	For dredging.	
William S. Carkin, Chicago, Ill	22 cents per cubic yard	
Williams & Upham, Houghton, Mich	14¾ cents per cubic yard	Contract awarded.
Lucian Moses, Skaneateles, N. Y	17 cents per cubic yard	
Chicago Dredging and Dock Company, Chicago, Ill	19½ cents per cubic yard	

Arrivals of vessels at and departure of vessels from the port of Duluth, Minnesota, during the year 1876.

	Steamers.	Propellers.	Sail-vessels.	Tonnage.	Men.
ARRIVALS.					
American vessels from American ports	15	132	28	116,384	3,757
Foreign vessels from foreign ports	29	98	5	50,481	2,736
American vessels from foreign ports		3	2	390	36
Total	44	233	35	167,255	6,529
DEPARTURES.					
American vessels from American ports	15	118	28	114,100	3,610
Foreign vessels from foreign ports	29	78	5	50,280	2,737
American vessels from foreign ports		16	2	2,180	188
Total	44	212	35	166,560	6,535

Statement of freight received and shipped from the port of Duluth, Minn., during the year 1876.

RECEIVED.

		Pounds.
Merchandise		20,739,136
Salt	32,736 barrels =	9,821,000
Coal		46,950,000
Total		77,510,136

SHIPPED.

		Pounds.
Merchandise		38,817,390
Flour	354,423 barrels =	70,884,600
Wheat		82,974,060
Total		192,676,050

X 2.

IMPROVEMENT OF NATURAL ENTRANCE TO THE BAY OF SUPERIOR.

The inner end of the Minnesota pier was repaired. Careful soundings in the entrance were made which showed that no shoaling had taken place.

The winds have cut down Minnesota Point at a place about 2 miles from the natural entrance, and already, during the prevalence of northeasterly storms, the waters of the lake have broken over the point and run into the bay. It is proposed to protect this place with a brush and stone protection, at a cost of about $1,000. The amount of work is so small that it will be prosecuted with hired labor.

The piers are in fair condition, but the wood superstructure put in place in 1868 shows in some places signs of decay, and before long must be renewed. This renewal can be made gradually. After the above brush protection is finished there will be about $1,500 still available for repairs and contingencies. I would recommend that an appropriation of $7,000 be asked for, to be used in repairs that may become necessary from damages from storms, or for the renewal of such parts of the superstructure as may be decayed.

At present there is no commerce at this port.

Superior City is in the collection-district of Mackinac.

Money statement.

July 1, 1876, amount available	$89 46
Amount appropriated by act approved August 14, 1876	3,000 00
	3,089 46
July 1, 1877, amount expended during fiscal year	589 46
July 1, 1877, amount available	2,500 00
Amount (estimated) required for repairs of existing works	7,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	7,000 00

Abstract of appropriations made for the improving of Superior Harbor, Wisconsin, showing how expended or to be expended.

Appropriations.	Construction and repairs of piers.	Dredging.	Total.
By act approved March 3, 1867	$63,000 00	....	$63,000 00
Allotted from act approved April 10, 1869	45,000 00	....	45,000 00
Allotted from act approved July 7, 1870	40,000 00	....	40,000 00
Allotted from act approved March 3, 1871	60,000 00	....	60,000 00
Allotted from act approved June 10, 1872	50,000 00	....	50,000 00
Allotted from act approved March 3, 1873	41,322 64	$22,628 16	63,950 80
Allotted from appropriation "repairs of harbors on the Northern Lakes," expended in protecting beach	*5,433 00	....	5,433 00
By act approved August 14, 1876	*3,000 00	....	3,000 00
	307,755 64	22,628 16	330,383 80

Original estimate for construction of piers	$309,716 00
Original estimate for dredging	25,000 00
Total	334,716 00

* Used for repairs and beach protections, and not included in original estimates.

APPENDIX Y.

ANNUAL REPORT OF MAJOR HENRY M. ROBERT, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 13, 1877.

SIR: Herewith I have the honor to transmit my annual report of operations at the several works in my charge during the fiscal year ending June 30, 1877.

Very respectfully, your obedient servant,

HENRY M. ROBERT,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Y 1.

ONTONAGON HARBOR, MICHIGAN.

This work was commenced in 1867.

The estimated cost of completing the improvement (consisting of two piers, each about 2,500 feet long, and dredging between them) was	$363,770
Appropriated since	170,600
Leaving still to be appropriated	193,170
Amount required for the fiscal year 1878–'79	30,000

The piers which have been built comprise about 1,300 feet of the 2,500 originally planned.

The operations at this harbor during the last fiscal year have comprised the completion of work under the contract of June 1, 1875, with Messrs. Ames & Emery, which was nearly completed when the last annual report was rendered. The following list shows in detail the amount of materials received from them during the year for riprapping, filling, leveling up, and putting on one course of superstructure over cribs 13 to 17, inclusive, west pier, and small repairs to the old work.

Superstructure over the ten cribs sunk in 1875–'76 is now being constructed under a contract, signed June 18, with Hiram J. Lutes, of Ontonagon, Mich. This work, it is expected, will be finished about October 1.

The recommendations heretofore made with regard to the prosecution of this work with liberal appropriations are renewed. The importance of the harbor consists in its position and availability as a harbor of refuge, the only one on a course of some 85 miles which can be entered during severe storms.

With the sum asked for 1878–'79 the piers will be extended by crib-work.

List of materials used under contract with Ames & Emery, dated June 1, 1875, from July 1, 1876, to the close of that working season.

Articles.	Quantities.	Price.	Amount.
Pine timber, framed .... cubic feet..	1,158	$0 24	$277 92
Drift-bolts .... pounds .	1,718.86	4½	77 35
Screw-bolts .... do....	36.60	6	2 20
Stone .... cords..	107.965	10 00	1,079 65
Brush .... do....	5.25	3 50	18 37
Total	....	....	1,455 49

This material was used as follows:

Riprap on west side of cribs 1, 2, 3, east pier	$159 55
Riprap on east side of crib 7, west pier	85 43
Riprap to pile revetment, west pier	20 00
Superstructure of piling, west pier	5 23
Superstructure on cribs 13 to 17, west pier	1,185 28
Total	1,455 49

NOTE.—The 10 cribs constructed by Ames & Emery (50′ × 20′ × 13½′, with one course of superstructure) cost $2,026.77 each, or $40.53½ per linear foot.

COMMERCIAL STATISTICS.

Name of harbor, Ontonagon, Mich.; collection-district, Superior; nearest light-house, Ontonagon, Mich.

Arrivals and departures of vessels for year ending December 31, 1876.

	Arrivals.			Departures.		
	No.	Tonnage.	Crews.	No.	Tonnage.	Crews.
Steamers	263	108,602	3,799	265	108,641	3,805
Sailing-vessels	14	2,314	75	16	2,353	79
Total	277	110,916	3,874	281	110,994	3,884

Exports for year ending December 31, 1876.

Lumber .... feet, board-measure..	1,920,000
Shingles .... number..	525,000
Fish .... packages..	90
Copper .... tons..	535
General merchandise .... tons..	382
Hay .... tons..	28

Imports for year ending December 31, 1876.

Lumber .... feet, board measure..	*26,182
Oats .... bushels..	11,824
Corn .... bushels..	2,954
Malt .... bushels..	400
Whisky .... barrels..	54
Sugar .... barrels..	369
Lime .... barrels..	356
Pork .... barrels..	269
Flour .... barrels..	3,381
Stone .... cords..	*162
General merchandise .... tons..	1,055

* Does not include lumber or stone used on the Government work.

The above information was obtained from M. A. Powers, deputy collector of customs, and Richard Stillman & Co., James Mercer, and John G. Parker, owners or agents in charge of all the docks in this harbor.

Money statement.

July 1, 1876, amount available	$4,793 74
Amount appropriated by act approved August 14, 1876	15,000 00
	19,793 74
July 1, 1877, amount expended during fiscal year	4,845 39
July 1, 1877, amount available	14,948 35
Amount (estimated) required for completion of existing project	193,170 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	30,000 00

Abstract of bids received May 26, 1877, by Major Henry M. Robert, Corps of Engineers, for building superstructure over ten cribs at Ontonagon Harbor, Michigan.

Bidders' names and residences.	Pine, 12 by 12 inches, framed, 14,400 linear feet.	Oak, 12 by 12 inches, framed, 500 feet, board measure.	Pine plank, laid, 27,000 feet, board measure.	White-oak piles, 300 linear feet.	Drift-bolts, 23,700 pounds.	Screw-bolts, N. & W., 500 pounds.	Cut spikes, 500 pounds.	Wrought spikes, 500 pounds.	Stone, 400 cords.	Brush, 50 cords.	Driving ten piles.	Amount.
Thurlby & Watson, L'Anse, Mich	$0 26	$40 00	$18 00	$0 27	$0 04	$0 08	$0 04	$0 06	$10 50	$3 00	$1 00	$9,729 00
Simon Emery, Hancock, Mich	23	50 00	15 00	10	03½	06	04	05½	11 00	3 50	3 50	9,289 00
Rosser & Winston, Minneapolis, Minn	23	25 00	16 00	10	04½	05½	08	10	10 00	3 00	6 00	9,180 50
Harvey & Hubbard, Manitowoc, Wis	24	19 00	15 00	05	03½	05	03	04	10 00	2 00	2 00	8,754 25
Edmond Ingalls, Duluth, Minn	24	50 00	13 00	20	03	05	05	05½	10 00	3 00	5 00	8,880 50
Thomas Keeler, Fulton, N. Y	21	50 00	18 00	25	04	06	04	04	9 00	3 00	3 00	8,408 00
John E. Thomas, Chicago, Ill	22	30 00	13 20	10	04	04½	05½	05½	8 90	3 50	6 50	8,394 90
McDougall & McLennan, Duluth, Minn	23	34 00	14 50	25	04	07½	07	08	7 85	3 00	3 00	8,176 00
Charles Fisher, Ashland, Wis	20	15 00	14 00	10	04	04	03	03½	9 00	3 00	5 00	8,096 00
E. Powell & Sons, Marquette, Mich	19½	45 00	16 00	10	04	06	04½	06	8 50	3 50	3 50	7,933 00
Hiram J. Lutes, Ontonagon, Mich	19	8 00	13 00	01	03	05	04	04	9 25	1 50	1 05	7,655 50

Y 2.

EAGLE HARBOR, MICHIGAN.

The amount expended on this harbor previous to 1874 was	$41,791 72
Estimate of 1874 for additional amount	231,570 64
Total estimate for present plan	273,362 36
Amount appropriated	87,000 00
Leaving to be appropriated	186,362 36
Amount required for fiscal year 1878-'79, which will place the harbor in as good condition as indicated in my modified plan of April 16, 1877, (see below)	$10,000 00

(For the history of previous plans, &c., see Report of Chief of Engineers for 1874, page 135.)

The work done during the past fiscal year was in continuation of the blasting and drilling, which was again renewed on May 24, 1877, and is now very nearly completed. A steam dredging equipment was employed by agreement with Messrs. Williams & Upham, of L'Anse, Mich., which is now at work removing the blasted rock from the bed of the channel. This is expected to be completed during the present season.

After this is done, in my opinion, no further work is required at this harbor except the building of a guiding-crib on each side of the cut, say 160 linear feet in all, costing about $10,000, which amount I would recommend to be appropriated for next season's work. This would enable vessels to use the cut with safety, and would improve the harbor as much as its importance justifies.

The work has, as before, been in immediate charge of my assistant, Mr. L. Y. Schermerhorn, to whose reports below I would refer for the details of the operations.

Money statement.

July 1, 1876, amount available	$9,933 99
Amount appropriated by act approved August 14, 1876	12,000 00
	21,933 99
July 1, 1877, amount expended during fiscal year	8,345 22
July 1, 1877, amount available	13,588 77
Amount (estimated) required for completion of existing project	186,362 36
Amount that can be profitably expended in fiscal year ending June 30, 1879	10,000 00

REPORTS OF MR. L. Y. SCHERMERHORN, ASSISTANT ENGINEER.

1.

DECEMBER 22, 1876.

SIR: I have the honor of submitting the following report on the operations at Eagle Harbor, Mich., during the past year.

The expectation of being able to renew drilling and blasting after the establishment of the winter of 1875 and 1876 was not realized; this was due to the unstable condition of the ice until January 15, 1876, followed by the closing of the harbor and the piling up and filling in of the ice over the entire entrance from the lake-bottom to a height of from 10 to 15 feet above the surface. This condition of the ice remained all winter, rendering work impossible. During the month of February a detailed survey was made of the ranges and soundings taken over the area of the proposed improvement. These soundings establish the location of the work to give the required width and depth of water-way, with the minimum removal of rock, the amount being 2,636 cubic yards.

The work preparatory to drilling and blasting was resumed May 20, and drilling and blasting began June 6.

The experience gained during the season of 1875 led to but few changes in the details of the work, the general plan being the same as in the previous year.

The charging and explosion of the holes followed close upon the drilling; the depth and diameter of holes were increased, also the average distance between holes; this demanded heavier charging, and was followed by better general results than those obtained last year.

The increased depth of the drill-holes carried them from 3 to 4 feet below proposed bottom. The filling up of drill-holes with the gravel and bowlders which cover the surface of the rock was a serious hinderance in the first season's work, but was almost entirely overcome by the use of the arrangement used; and, since this difficulty was paramount to all others, a description of the method used to overcome it may be desirable. A cast-iron plate, weighing about 125 pounds, carried a pipe 4 inches exterior diameter and about 4 feet in length; this passed through a hole in the center of the casting slightly larger than the pipe, which was prevented from withdrawing through the casting by an enlargement of its lower end; a considerable adjustment was permitted between the position of the casting, when on the bottom, and the pipe. The casting and pipe was moved and handled by ropes attached thereto, and carried up to the drilling-platform.

In starting a hole, the pipe and casting were slightly raised from the bottom, and the drill-steel passed through the pipe and attached to the drill; when the steel was in position, the casting and pipe were lowered to the bottom. The early blows of the steel knocking aside the gravel and bowlders allowed the casting to assume a stable position on the bottom, the ropes being left quite slack; the entrance of the drill-steel into the rock was followed for a short distance by the pipe, thereby shutting out the entrance of the drift to the hole; after the second drill-steel was inserted, being of smaller diameter than the first, a second pipe, 3 inches in diameter and about 4 feet in length, was dropped over the drill-steel, passing inside the pipe attached to the casting and entering the hole to about the depth attained by the first steel. Upon the completion of the hole, the casting and attached pipe were lifted by the ropes attached thereto, leaving the 3-inch pipe inserted in the hole; there it remained until the holes were charged, and only withdrawn just previous to insertion of the exploder into the hole. This arrangement of drill-pipes had been previously used by Assistant E. P. North, at Ahnapee, Lake Michigan.

Upon July 25, the drilling and blasting having been completed over the west half of the work, it became necessary to next take up the area covered by the present used channel, and pass vessels in over the area just completed; previous to doing so it was necessary to remove such of the blasted rock as gave a less depth than 12 feet. This was done through the aid of the diver, and after the removal of 40 cubic yards a careful examination showed that the width of 65 feet gave a minimum depth of 12 feet.

The target-ranges were changed to correspond with the new temporary entrance. On the 8th of August, and during the remainder of the season, the commerce of the port entered thereby.

Vessel owners and captains were previously advised of the intended change both by advertisement and personal interview; and although vessels were obliged to pass within 10 feet of the drilling platform, yet no accident or inconvenience either to the work or passing vessels occurred during the season.

DETAILS OF THE WORK FOR SEASON OF 1876.

Number of holes drilled	309
Aggregate depth drilled, feet	1,945
Average depth per hole, feet	6.3
Number of holes charged and fired	275
Aggregate amount of No. 1 dynamite used, pounds	775
Aggregate amount of No. 2 dynamite used, pounds	3,260
Average amount of No. 1 per hole, pounds	2.8
Average amount of No. 2 per hole, pounds	11.9
Number of drills sharpened	132
Depth drilled per drill sharpened, feet	14.7
Aggregate amount of steel used, pounds	40
Aggregate amount of steel used per foot drilled, pounds	.002
Aggregate number of hours drilling	727
Average amount drilled per hour, feet	2.67
Aggregate area worked over, square feet	16,600
Average area covered per hole exploded, square feet	60.4
Average distance between holes, feet	7.7
Diameter of drill-holes, inches	4 to 2¾

The following shows the cost of the principal subdivisions of the work, viz, drilling and blasting:

DRILLING.

Drilling, labor		$629 96
Sharpening drills, labor		18 84
Blacksmiths' coal, 2 tons, at $10		20 00
Fuel, 46 cords wood, at $3.50		161 00
Construction and maintenance platform, labor		333 83
Aggregate cost		1,163 63
Cost per linear foot drilled	$0 59	
Cost per hole 6.3 feet in depth	3 62	

BLASTING.

Blasting, labor		$329 86
Fuel, 24 cords wood, at $3.50		84 00
Dynamite No. 1, 775 pounds, at 90 cents		697 50
Dynamite No. 2, 3,260 pounds, at 45 cents		1,467 00
Exploders, 500, at 30 cents		150 00
Aggregate cost		2,728 36
Cost of charging and firing, per hole	$9 92	
Cost of drilling, per hole	3 62	
Aggregate cost per hole drilled, charged, and fired	13 54	

Since the object of the work in hand may be summed up under the heads of drilling and blasting, and since all collateral work is but part thereof, the foregoing statements of cost do not give the entire cost of such drilling and blasting, but only the portion which immediately and most directly applies.

At the completion of the work such statements can be easily compiled from the detailed accounts which are kept of the several items. The organization, application, and pay of the labor force has been as follows:

No.	Designation.	Application.	Pay.
1	Overseer	Detailed supervision force	$120 per month.
1	Diver	Diver	29 cents per hour.
1	Machinist	Charge of engine and boiler	27 cents per hour.
1	First-class laborer	Diver's attendant	22 cents per hour.
2	Second-class laborer	Drill-runners	20 cents per hour.
4	Third-class laborer	Drill-helpers and jobbers	17¼ cents per hour.
1	Fourth-class laborer	Cleaning holes and errands	15 cents per hour.

The general plan for the improvement of Eagle Harbor seems to have always contemplated, besides the removal of the rock obstructing the entrance to a depth of 14 feet, the construction of breakwaters inclosing the harbor. This latter part of the general plan assumes either the possibility of utilizing the harbor for refuge, or the necessity of protection to shipping while in the harbor. A careful study of these points has led me to conclude that neither of the above assumptions is justified by the facts in the case. In my report of last year the requirements of the lake commerce, and the possibility of adapting the port of Eagle Harbor to such requirements, were considered with some detail.

The observations of the past year have strengthened my previous conclusions, and it may be permissible to briefly review the question.

About 1,000 feet outside of the proposed entrance is a dangerous reef covered with from 4 to 12 feet of water; the line of approach carries vessels within 200 feet of the westerly end of this reef, upon which, in a gale, the waves break heavily, producing a broken and dangerous sea, not only at this point, but over the space intervening between this reef and the entrance to the harbor. A still heavier and more dangerous sea breaks on the reef at the entrance; this added to the fact that a belt of dangerous water, from one-half to three-fourths of a mile in width, extends for a long distance on each side of the entrance, making it impossible for vessels to approach the harbor with safety during a storm.

The lake propellers steer heavily, and cannot be handled quickly and surely in restricted entrances, and here a slight drifting from the direct line of approach would carry a vessel to destruction. Such dangers incident to approach and entrance seem to preclude the utilization of the harbor for purposes of refuge when most needed, viz, during a gale.

The only remaining reason which would demand breakwaters inclosing the harbor would be the protection of vessels from the effects of a storm arising while lying at the dock discharging or receiving cargoes; an emergency which has arisen *three* times during the past two years. In these cases the vessels were able to safely ride out the storm by means of lines attached to the dock-piles, and in each case without serious danger or injury.

The amount of freight handled at this port in any one cargo is comparatively small, and hence delaying vessels at the dock for short intervals. In rough or dangerous weather vessels do not, nor will not, under any circumstances, approach the port, and in fine weather the time spent at dock, except in rare cases, is not long enough to allow a change from fair to foul weather. I am unable to learn of a single loss to vessels lying at the dock during a gale.

In view of the foregoing reasons the present needs of commerce do not seem to justify the constructions to the extent suggested in previous plans.

With such convictions I would most respectfully submit essentially the same plan as embodied in my previous report, *i. e.*, the removal of the rock to a depth and for a width as hitherto proposed, and the construction of *guiding-cribs* on each side of the entrance and parallel to the line of entrance. Such cribs, besides defining clearly the entrance, would guard vessels from drifting or being carried on to the dangerous parts of the reef on each side of the entrance. These cribs might have the following general dimensions: West cribs, 90 feet in length; east cribs, 40 feet in length; width, 20 feet; average height, 17 feet.

This would give the cribs a height of 6 feet above the general summer level of the past two years.

The general plan of work for 1877 might then be summarized as follows: The completion of drilling and blasting; the removal of the rock by a steam dredge; the construction of the guiding-cribs. The progressive drilling and blasting yet to be done will require one month's work; the dredging may require two months' work; and as it is highly probable that, as the dredging progresses, some auxiliary drilling and blasting will be necessary, it will be safe to assume that the drilling and blasting yet to be done will cover two months, and requiring during this time the full force necessary for continuous work.

Should it be deemed expedient to undertake the construction of the cribs, it could be carried on very advantageously in the same general time as the foregoing, thereby enabling a more complete utilization of spare time from the drilling force, and such amounts of rock as might be judiciously applied from the excavation by the dredge.

Should more rock be required than would be economically afforded by the dredge, (and such would be the case,) the general plant and force on hand could be relied on to furnish rock in such quantities and at such times as should be required. I would, therefore, submit the plan for the contemporaneous removal of the rock and the construction of the cribs by day's labor.

Timber could be purchased in open market at Houghton and delivered at Eagle Harbor at very advantageous prices to the Government.

It would also be more satisfactory to have the dredging done by the day instead of by the cubic yard, since no contract could be entered into without the Government paying unduly for the element of uncertainty as to the exact condition of the blasted rock, an element which would enter largely into any estimate made by a contractor. A contract, such as mentioned in my previous report, could be made, but on a cheaper basis, viz, fully manned and equipped dredge, tug-boat, and stone scows at the price of $135 per day for the first 30 days, and $125 per day for each day thereafter when at work, and $50 per day for each day when not at work from causes not their own; all time to be considered as lost when dredge is unable to work through accident thereto, or from necessary repairs; the day to be counted as ten hours.

On the foregoing basis the following estimate is made for the cost of completing the work:

2 months' labor, drilling and blasting, at $700	$1,400 00
400 pounds No. 1 dynamite, at 90 cents	360 00
800 pounds No. 2 dynamite, at 45 cents	360 00
60 days' dredging, at $130	7,800 00
130 linear feet cribbing, 17 × 20 feet, at $42	5,460 00
Superintendence and contingencies	1,620 00
	17,000 00

The light-house reservation could furnish all extra rock for filling and at a distance of less than one-half mile from the work.

It would be of the first importance to utilize the uniformly calm and reliable season which occurs during the months of June and July, and any plan for the season of 1877 should recognize the value of full preparation and an early starting of the work.

ESTIMATE FOR GUIDING-CRIBS.

	Feet.
Average depth of water referred to low water, 1868	9.0
Average depth of water referred to past two seasons	11.0
Height of cribs above average summer level	6.0
Total height of cribs	17.0
Width of cribs	20.0
Total length, (west side 90 feet, east side 40 feet)	130.0
Bill of materials:	
10,400 cubic feet timber, at 24 cents	$2,496 00
10,800 pounds iron, at 4½ cents	486 00
240 cords filling, at $10	2,400 00
	5,382 00

$\frac{\$5.382}{130'}$ = $41.40 per linear foot.

The cribs are intended to be placed so that their ends stand in 10 feet of water, (referred to 1868,) or 12 feet, as the summer level has been during the past two seasons. I think it is safe to assume that low water of 1868 is 2'.0 below the stage during navigation.

Altogether the past season has been very favorable for the progress of the work, the drilling and blasting would have been completed by the end of the season, but for the unexpected loss of time incurred by the removal of rock from the temporary entrance.

The lake surface has been continuously about 0'.8 higher than it was last year; the maximum was reached the last of August, when it stood 3 feet above the low-water mark of 1868.

During the winter of 1875–'76, shortly after the closing of the harbor, the northerly winds drove in and piled the ice upon the inner reef to a height of from 10 to 15 feet above the lake surface, presenting a continuous ice-barrier from shore to shore, and completely inclosing the harbor. In the spring this was broken up by heavy storms, and moved away in the form of icebergs. This ice formation rests, over very considerable areas, upon the lake bottom, and during the dissolution in the spring large quantities of gravel and bowlders which were embedded in the base are transported from place to place; this, added to the disturbing action of heavy norhherly gales, will probably have the effect in time of partially filling up the deepened entrance.

The boats, tools, machinery, and supplies are in good condition, and hardly any expenditure will be necessary in this direction for carrying on the work of 1877.

I desire to recognize tne efficient services rendered by Overseer J. F. Huston during the past two seasons; and to his energy, ingenuity, and interest, the progress of the work is in a large degree due.

The following commercial statistics have been carefully compiled from the warehouse accounts, consignors' and consignees' books, and from office memoranda, under my personal supervision:

COMMERCIAL STATISTICS.

Exports for years ending December 31, 1875 *and* 1876.

Articles.		1875.		1876.	
		Amount.	Value.	Amount.	Value.
Beer	barrels	62	$620 00		
Coal	pounds	10,600	132 00		
Copper	do	5,204,342	1,092,911 00	4,119,333	$906,2[illegible]3 00
Flour	barrels	86	700 00		
Feed	pounds	9,000	180 00		
Fish	barrels	65	520 00	67	560 00
Furniture	pounds			4,200	1,000 00
Fuse	do			2,300	800 00
Hides	do	20,450	2,050 00	39,000	4,000 00
Household goods	do	16,000	1,000 00	35,500	2,000 00
Hardware	do			24,800	2,400 80
Iron	do	39,200	1,440 00	10,000	500 00
Machinery	do	12,500	1,800 00	19,500	2,500 00
Miscellaneous	do	29,800	6,000 00	130,600	10,000 00
Oats	do	16,500	368 00		
Oil	barrels	3	60 00		
Provisions	pounds	20,300	2,000 00		
Potash	do			23,000	1,000 00
Silver	do			333	5,000 00
Tallow	do			3,700	300 00
Total			1,109,061 00		936,393 00

Imports for years ending December 1, 1875 *and* 1876.

Articles.	1875.		1876.	
	Amount.	Value.	Amount.	Value.
Apples ....barrels..	....	....	962	$2,886 00
Bricks ....number..	68,000	$868 00	27,000	251 00
Corn ....pounds..	446,980	8,940 00	325,946	6,520 00
Cattle ....number..	363	18,150 00	225	11,250 00
Coal ....pounds..	829,066	8,290 00	471,251	4,700 00
Dry goods ....do....	27,196	30,000 00	62,096	60,000 00
Feed ....do....	748,893	14,980 00	383,611	7,670 00
Flour ....barrels..	2,624	21,000 00	3,444	27,550 00
Groceries ....pounds..	854,360	85,000 00	525,195	48,000 00
Hay ....do...	564,846	7,000 00	196,795	2,000 00
Hogs ....number..	338	6,700 00	255	5,100 00
Hardware ....pounds..	97,189	11,500 00	153,103	17,360 00
Horses ....number..	4	600 00	20	3,000 00
Iron ....pounds..	179,296	17,900 00	109,537	11,000 00
Lumber ....feet..	117,000	1,400 00	191,025	2,400 00
Leather ....pounds..	6,750	2,700 00	5,309	2,121 00
Lime and cement ....barrels..	1,415	2,830 00	835	2,100 00
Laths ....number..	....	....	13,000	130 00
Machinery ....pounds..	371,675	48,500 00	94,611	15,000 00
Miscellaneous ....do....	139,932	25,000 00	230,183	45,000 00
Malt ....do ...	....	....	48,606	4,500 00
Oil ....barrels..	210	4,200 00	189	3,800 00
Oats ....pounds..	651,543	13,030 00	795,958	15,920 00
Provisions ....do...	402,141	40,500 00	218,933	22,000 00
Potatoes ....do...	208,148	2,070 00	95,527	1,420 00
Powder ....do ...	46,500	13,250 00	14,000	4,200 00
Salt ....barrels..	124	496 00	171	684 00
Shingles ....number.	396,000	1,584 00	324,750	1,720 00
Sheep ....do ..	205	2,050 00	210	2,100 00
Whisky ....barrels..	94	9,000 00	80	8,000 00
Wine and beer ....do....	142	1,704 00	205	2,400 00
Total	....	399,252 00	....	340,841 00

	1875.	Value.	1876.	Value.
Aggregate tonnage, exports	2,727	$1,109,081 00	2,217	$936,393 00
Aggregate tonnage, imports	3,776	399,252 00	3,200	340,841 00
Total	6,503	1,508,333 00	5,417	1,277,234 00

Statistics of vessels entering the harbor during the season of 1875 *and* 1876.

Year.	No. steamers.	No. sailing-vessels.	Aggregate tonnage.	No. crews.	No. drawing 7'.0.	No. drawing 11'.0.	No. drawing 12'.0.	No. drawing 12½'.0.	No. drawing 13'.0.	No. drawing 13½'.0.
1875	135	......	83,240	3,010	20	51	30	31	3	......
1876	121	7	77,500	2,700	7	44	51	12	13	1

First vessel arrived in port May 14.
First vessel left port November 27.
Length of navigable season 198 days.

Very respectfully, your obedient servant,

L. Y. SCHERMERHORN,
Assistant Engineer.

Maj. HENRY M. ROBERT,
Corps of Engineers, U. S. A.

2.

EAGLE HARBOR, LAKE SUPERIOR,
June 30, 1877.

SIR: I have the honor to report the following summary of work during the season of 1877 up to June 30:

Number of holes drilled: May, 21; June, 44 = 65.
Aggregate depth of holes drilled: May, 173 feet; June, 357 feet = 530 feet.
Area drilled over: May, 1,000 square feet; June, 3,300 square feet = 4,300 square feet.
Area remaining to be drilled, 2,000 square feet.

With the exception of the above 2,000 square feet the progressive drilling and blasting is completed. The blasted rock is being removed with a dredge. It will be necessary, as the dredging progresses, to do some auxiliary drilling and blasting to break up the large masses and remove high points.

Drilling was commenced this season on May 24. There seems every reason to believe that the work can be entirely completed by September 1.

Very respectfully, your obedient servant,

L. Y. SCHERMERHORN,
Assistant Engineer.

Maj. H. M. ROBERT,
Corps of Engineers, U. S. A.

Y 3.

MARQUETTE HARBOR, MICHIGAN.

The breakwater at this harbor was built 10 feet longer than originally contemplated, at a cost of $306,255.75, which was $78,873.83 less than the amount estimated for. It should be extended eventually 400 linear feet farther, which would cost, it is estimated, $68,000.

During the past fiscal year the owners of the bark Oscar Townsend paid the cost of repairing an injury to the breakwater made by that vessel. Some further repairs were made by the officer in charge of the work during the year; similar repairs are the only operations contemplated during the present season.

COMMERCIAL STATISTICS.

Name of harbor, Marquette, Mich.; collection-district, Superior; nearest light-house, Marquette.

Arrivals and departures of vessels during year ending December 31, 1876.

	Arrivals.			Departures.		
	No.	Tonnage.	Crews.	No.	Tonnage.	Crews.
Steamers	481	466,775	10,299	490	478,581	10,375
Sailing-vessels	283	165,698	2,413	298	162,663	2,339
Total	764	632,473	12,712	788	641,244	12,714

Exports for the year ending December 31, 1876.

Lumber, feet, board measure	2,939,000	Pig-iron, tons	31,999
Sashes, number	390	Iron ore, tons	458,273
Doors, number	70	Scrap-iron, tons	220
Fish, packages	148	Berries, bushels	1,701
Fish, tons	167	Hogs, number	49
Sandstone, tons	520	Sheep, number	87
Powder, kegs	3,720	Horses, number	13
Merchandise, tons	1,763		

Imports for the year ending December 31, 1876.

Merchandise, tons	6,996	Bar-iron, tons	230
Hay, tons	1,410	Sugar, barrels	580
Oats, bushels	33,631	Bricks, thousand	205,000
Corn, bushels	3,920	Coke, tons	2,025
Malt, bushels	2,000	Potatoes, bushels	1,600
Lath, thousands		Oil, barrels	840
Whisky, barrels	500	Railroad-iron, tons	210
Feed, tons	364	Slate, tons	30
Coal, tons	53,720	Flour, barrels	736
Limestone, tons	6,572		

The above information was obtained from J. H. Chandler, collector.

Money statement.

July 1, 1876, amount available	$1,083 45
Amount appropriated by act approved August 14, 1876	2,000 00
	3,083 45
July 1, 1877, amount expended during fiscal year	592 55
July 1, 1877, amount available	2,490 90
Amount (estimated) required for completion of project recommended	68,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	20,000 00

which will be applied to the extension of the breakwater in the manner proposed.

Y 4.

MENOMONEE HARBOR, MICHIGAN AND WISCONSIN.

Estimated cost of present plan of improvement	$212,000 00
Appropriated to date	133,000 00
Leaving to be appropriated	79,000 00
Amount required for the fiscal year 1878–'79	25,000 00

Under the contract of June 1, 1875, with the Menomonee Dredging Association, which was extended to September 30, 1876, 40,584.2 cubic yards of material were removed from the river-channel. This quantity, with that done in the previous year, made a total of 134,061.8 cubic yards of dredging done under the above contract, at 14½ cents per cubic yard.

The south pier was severely injured by undermining during a freshet in May, 1876, as mentioned in the last annual report. The injury was repaired, and some necessary refilling done on the north pier, at a total expense for labor and materials of $2,500.31.

During the fiscal year 83,000 cubic yards of dredging was done in the harbor by private parties.

The appropriation of August 14, 1876, will be expended this summer in building and placing in position five cribs, in extension of the piers. A contract for this work was signed June 18, with Truman & Schroeder, of Manitowoc, Wis., after due advertisement.

Amount that can be profitably expended in fiscal year ending June 30, 1879. $25,000 00

This amount will, if appropriated, be used in extending the piers, and in doing some dredging in the channel.

COMMERCIAL STATISTICS.

Name of harbor, Menomonee, Mich. and Wis.; collection-district, Superior; nearest light-house, Green Island, Wis.

Arrivals and departures of vessels during year ending December 31, 1876.

	Arrivals.			Departures.		
	Number.	Tonnage.	Crew.	Number.	Tonnage.	Crew.
Steamers	108	43,200	1,728	107	42,791	1,712
Sailing-vessels	504	130,500	2,736	498	128,193	2,693
Total	612	173,700	4,464	605	170,984	4,405

Exports for year ending December 31, 1876.

Lumber, feet, board-measure.	140,000,000	Laths ....number.	3,000,000
Pickets ....number.	1,800,000	Pig-iron ....tons.	2,200
Posts ....number.	240,000	Fish	13,000
Shingles ....number.	20,000,000	Ice............tons.	1,000

Imports for year ending December 31, 1876.

Hay............tons.	850	Stone ....cords.	500
Merchandise ....tons.	1,250	Beef ....barrels.	1,950
Flour ....barrels.	7,400	Grain ....bushels.	135,000
Salt ....barrels.	950	Feed ....tons.	700
Lime ....barrels.	1,000	Potatoes............bushels.	500
Pork............barrels.	1,375	Brick............thousands.	300
Wood ....cords.	500		

The above information was obtained from J. R. Brooks.

Money statement.

July 1, 1876, amount available............	$12,245 47
Amount appropriated by act approved August 14, 1876............	8,000 00
	20,245 47
July 1, 1877, amount expended during fiscal year	10,714 24
July 1, 1877, amount available............	9,531 23
Amount (estimated) required for completion of existing project............	79,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	25,000 00

List of materials and labor used in repairs to piers.

Articles.	Quantity.	Price.	Amount.	
			North pier.	South pier.
Stone filling............cords	281.73	$4 50	$372 60	$895 18
Stone riprap............do...	163.25	4 50	....	734 62
Facings ....do...	301⅓	1 50	54 00	398 25
Draft bolts............pounds	585	3¾ cents.	....	21 94
Spikes, wrought............do..	117	6 cents.	....	7 02
Lumber............feet, b. m.	588	8 00 per M	....	4 70
Labor, carpenter's ....days	3	2 50	....	7 50
Labor, common............do...	3	1 50	....	4 50
			426 60	2,073 71
Total			....	2,500 31

Abstract of bids received May 19, 1877, by Major Henry M. Robert, Corps of Engineers, for building and placing five cribs, (50 by 20 by 16½ feet,) at Menomonee Harbor, Michigan and Wisconsin.

Bidders' names and residences.	Pine timber, 12 by 18 inches, 500 linear feet, framed.	Pine timber, 12 by 12 inches, 1,600 linear feet, framed.	Oak timber, 12 by 12 inches, 4,300 feet, board-measure, framed.	White-oak or northern-pine piles, 1,100 linear feet.	Pine plank, 3 by 12 inches, 16,000 feet, board-measure.	Drift-bolts, 1¼ inches square, 22,000 pounds.	Screw-bolts, 300 pounds.	Cut spikes, 7-inch, 500 pounds.	Wrought spikes, 9-inch, 100 pounds.	Stone, 400 cords.	Brush, 30 cords.	Chain, 1-inch, 4,700 pounds.	Laying plank, 16,000 feet, board-measure.	Driving piles, 36.	Amount.
B. B. Locklin, Sheboygan, Wis.	$0 35	$0 26	$29 00	$0 8	$10 50	$0 4	$0 5½	$0 3	$0 4½	$6 00	$3 00	$0 7	$3 00	$2 00	$8, 630 70
Green Bay Dredge & Driver Company, Green Bay, Wis.	33	24	30 00	8	9 00	3½	5	4	5	5 00	3 00	6	2 00	2 00	7, 657 00
A. & A. Hart, Green Bay, Wis.	30	21	30 00	15	9 00	4	7	4	5	3 90	2 50	9	150	2 50	7, 096 00
Truman & Schrœder, Manitowoc, Wis.	20	22	15 00	6	7 50	3	4	3½	3½	4 60	1 00	4¾	100	2 50	6, 782 75

Y 5.

GREEN BAY HARBOR, WISCONSIN.

Estimated cost of present plan, (1872 and 1874,) with a small annual appropriation for preserving harbor	$75,000 00
Appropriated since	48,000 00
Leaving to be appropriated	27,000 00
Amount required for fiscal year ending June 30, 1879	15 000 00

The importance of this work is sufficiently indicated by its position at the mouth of the Fox River, it really forming a part of the improvement of the Fox and Wisconsin Rivers. The only operations at this harbor during the past fiscal year were the repairs of the east and west pier revetments where damaged by the ice, and extension of the pile protection of the east pier. The work was done by hired labor and purchase in open market, as the season was too far advanced by the time the funds became available to permit of making the regular contract after advertising. The repairs were commenced October 9 and completed November 24.

The appropriation of August 14, 1876, will be expended this season in dredging on the line of previous work, and a contract therefor was signed June 21, after due advertising, with the Green Bay Dredge and Driver Company. The work proposed in 1878–'79 is the continuation of the improvement by dredging.

List of materials and labor used in repairs and protection of piers.

Articles.	Quantities.	Price.	West pier.	East pier.	Pile protection.
Pine piles ......lin. ft..	5,902	6 cents.......	$126 66	$135 72	$91 74
Piles driven ......ft..	3,009	9 cents	103 68	89 82	77 31
Pine timber, 6 by 12 inches ......lin. ft..	2,034	7 cents.......	44 80	80 71	16 87
Framing-timber ......do ..	1,181	18 to 50 cents	115 20	103 66	59 00
Stone ......cords..	10.72	$5..........	....	35 00	18 60
Brush ......do...	43	$3..........	....	84 00	45 00
Spikes, wrought ......pounds..	278	5 cents.......	....	13 90	....
Drift-bolts ......do...	758	4 cents.......	....	30 32	....
Screw-bolts and washers......do...	2,520½	6 cents.......	107 58	27 51	16 12
Dredging ......lin. ft. of pier..	75	....	....	100 00	....
Drawing piles......each..	69	$1 50........	....	103 50	....
			497 92	804 14	324 64
Total cost					$1,626 70

The work was done by the Green Bay Dredge and Driver Company.

COMMERCIAL STATISTICS.

Name of harbor, Green Bay, Wis.; collection-district, Milwaukee, Wis.; nearest light-house, Grassy Island.

Arrivals and departures of vessels during year ending December 31, 1876.

	Arrivals.			Departures.		
	No.	Tonnage.	Crew.	No.	Tonnage.	Crew.
Steamers	202	98,648	3,295	200	98,180	3,276
Sailing-vessels	120	27,940	841	118	27,530	825
Total......	322	126,588	4,136	318	125,710	4,101

Exports for the year ending December 31, 1876.

Lumber ... feet, board-measure..	15,900	Wheat .... bushels..	447,410
Shingles .... thousand..	68,454	Salt .... barrels..	2,021
Merchandise .... tons..	1,579	Cattle .... head..	460
Merchandise .... packages..	20,527	Oil, carbon .... barrels..	640
Pig-iron .... tons..	11,908	Staves .... thousand..	5,271
Fish .... packages..	25,263	M. T. oil .... barrels..	6,440
Fish .... barrels..	4,780	Ice .... tons..	2,500
Flour .... barrels..	23,151		

Imports for the year ending December 31, 1876.

General merchandise...... tons..	1,491	Liquors .... packages..	1,870
General merchandise . packages..	69,860	Railroad-iron .... tons..	1,946
Carbon oil .... barrels..	3,937	Stone .... tons..	922
Pork .... barrels..	1,747	Salt .... tons..	550
Cement .... barrels..	7,240	Apples .... barrels..	6,892
Iron-ore .... tons..	41,979	Salt .... barrels..	30,684
Coal .... tons..	7,710		

The above information was obtained from J. R. Morris, deputy collector.

Money statement.

July 1, 1876, amount available	$419 16
Amount appropriated by act approved August 14, 1876	8,000 00
	8,419 16
July 1, 1877, amount expended during fiscal year	2,274 73
July 1, 1877, amount available	6,144 43
Amount (estimated) required for completion of existing project	27,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	15,000 00

Abstract of bids received May 19, 1877, by Maj. H. M. Robert, Corps of Engineers, for dredging at Green Bay Harbor, Wisconsin.

Bidders' names and residences.	Dredging.
Green Bay Dredge and Driver Company, Green Bay, Wis	12¼ cents per cubic yard.

Y 6.

HARBOR OF REFUGE AT STURGEON BAY CANAL, WISCONSIN.

Original estimate	$180,000 00
Appropriated since	50,000 00

No appropriation was made since 1874. Nothing has been done since that year. The pile piers need repairs, for which the small sum on hand will be expended this season, though it will do but little. The ship-canal company has resumed work this season excavating the canal, and when this is finished the harbor will become an important point for shipping. Five thousand dollars should be appropriated to provide for repairs needed and likely to be required by the end of the present fiscal year.

Money statement.

July 1, 1876, amount available	$401 21
July 1, 1877, amount available	401 21
Amount (estimated) required for completion of existing project	130,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879, for repairs	5,000 00

Y 7.

AHNEPEE HARBOR, WISCONSIN.

Original estimate, (1870)	$370,000 00
Appropriated to 1875	75,000 00
Revised estimate for completing the harbor, (see Report of Chief of Engineers, 1876, Appendix W 7)	95,000 00
Appropriated since, (act of August 14, 1876)	8,000 00
Leaving to be appropriated	87,000 00
Amount required for the fiscal year 1878–'79	22,000 00

The United States dredge was put in order this spring, and commenced taking out the rock blasted in the spring of 1876. About one-third of the blasted rock will be dredged by July 15, the main object being to test the result of the blasting operations for guidance in the future. As soon as this is done, the dredge will be removed to Fort Washington. After due advertising, a contract was signed, June 18, with Truman & Schrœder, of Manitowoc, Wis., for the construction of superstructure over the seven cribs sunk in 1875. This work is now under way, and will probably be finished by September 15; to it the appropriation of August 14, 1876, is being applied.

During the fiscal year 1878–'79, it is proposed to continue the blasting and removal of rock, in accordance with the recommendations of the Board of Engineers, (see Appendix W 7, Report Chief of Engineers 1876;) 8,000 cubic yards can be removed with the sum asked for.

There has been some trouble in carrying on the work at this harbor, owing to the fact that the title to nearly the entire site of the harbor was claimed by a private party, who also owned the pier-dock. I understand that the net income from the latter is at least $8,000 a year, and it will be a complete loss when the harbor is completed.

To avoid paying dockage, some vessels entering the harbor discharged cargo on to scows. To prevent this the dock-owner had a boom placed across the entrance to the bayou, claiming that it (the bayou) was excavated on his private property. In the fall, during a storm, the sea broke through the bank between the bayou and the lake, filling up the bayou. I declined to protect the bank, or to re-excavate the bayou, as long as there was any question about its being public property, and requested the village authorities to take such legal steps as would relieve the officer in charge of the harbor from all embarrassment in carrying on the work. Just before the dredging began this year, I found that there was a liability of an injunction being obtained to restrain the United States from dredging out the rock. I immediately proceeded to Ahnepee, and after a full conference with the village trustees and the owner of the dock and harbor site, the whole matter was amicably arranged, the owner of the bed of the stream (which had never been meandered) admitting that he could not legally prevent the removal of the rock therefrom. Since then he has deeded the site of the bayou and 10 feet on each side of the piers to the village, so that there is now no legal difficulty in carrying out the plan of improvement as far as the appropriations will allow.

COMMERCIAL STATISTICS.

Name of harbor Ahnepee, Wis.; collection-district, Milwaukee, Wis.; nearest light-house, Twin River Point.

Arrivals and departures of vessels during the year ending December 31, 1876.

	Arrivals.			Departures.		
	No.	Tonnage	Crew.	No.	Tonnage	Crew.
Steamers	420	147,346	8,860	420	147,346	8,860
Sailing-vessels	262	19,725	1,317	261	19,575	1,309
Total	682	167,071	10,177	681	166,921	10,169

Exports for the year ending December 31, 1876.

Lumber, ft., B. M	1,600,000	Eggs, doz	5,000
Bark, cords	800	Fish, pkgs	1,100
Bricks, No	100,000	Shingles, No	2,000,000
Hides, pounds	7,500	Potatoes, bush	2,500
Wheat, bush	85,210	Butter, tons	40
Barley, bush	10,000	Oats, bush	800
Rye, bush	1,500	Barrel-hoops, No	150,000
Peas, bush	5,000	Wool, sacks	34
Wood, cords	8,000	Rags, bales	759
Leather, pounds	17,600	Reapers, No	16
Ice, tons	3,000	Wagons, No	10
Hay, tons	10	Dressed hogs, number	150
Ties, No	59,000	General merchandise	49
Posts, No	95,050		

Imports for the year ending December 31, 1876.

Merchandise, tons	1,200	Beef, bbls	110
Salt, bbls	1,300	Reapers, No	225
Whisky, bbls	130	Plows, No	269
Flour, bbls	1,550	Threshers, No	13
Sugar, bbls	325	Seeders, No	167
Pork, bbls	165	Hay-rakes, No	39

The above information was obtained from Conway Bros. and G. W. Young.

Money statement.

July 1, 1876, amount available	$284 91
Amount appropriated by act approved August 14, 1876	8,000 00
	8,284 91
July 1, 1877, amount expended during fiscal year	1,287 86
July 1, 1877, amount available	6,997 05
Amount (estimated) required for completion of existing project	87,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	22,000 00

Abstract of bids received by Maj. Henry M. Robert, Corps of Engineers, May 19, 1877, for building superstructure on seven cribs at Ahnepee Harbor, Wisconsin.

Bidders' names and residences.	Pine timber, 12 by 12 inches, 10,000 linear feet, framed.	Oak timber, 12 by 12 inches, 500 feet, board-measure, framed.	Pine plank, 3 by 12 inches, 1,000 feet, board-measure.	White oak or Northern pine piles, 300 linear feet.	Drift-bolts, 1¼ inches square, 16,000 pounds.	Screw-bolts, nuts, and washers, 300 pounds.	Cut spikes, 7-inch, 300 pounds.	Wrought spikes, 9-inch, 300 pounds.	Handling stone, 300 cords.	Brush, 100 cords.	Plank laid, 10,000 feet, board measure.	Driving piles, 10.	Amount.
D. W. Stebbins, Ahnepee, Wis	$0 29	$25 00	$14 00	$0 16	$0 03¼	$0 05	$0 03½	$0 05	$2 00	$3 00	$2 50	$5 00	$4,505 00
Knapp & Gillen, Racine, Wis	26	40 00	10 00	15	03½	06	03	05	2 00	4 00	8 50	5 00	4,407 00
Hanson & Scove, Two Rivers, Wis	27	35 00	12 00	15	02 7/10	06½	03½	03 7/10	2 00	2 00	2 00	4 00	4,103 90
B. B. Locklin, Sheboygan, Wis	26	28 30	11 00	10	04	05½	03	04½	1 10	2 75	3 25	2 00	3,987 15
George R. Roberts, Ahnepee, Wis	23	20 00	12 00	15	03	05	03	04	1 50	2 00	2 00	5 00	3,599 00
Green Bay Dredge and Driver Company, Green Bay, Wis	20	30 00	9 00	06	03½	05	04	05	1 50	2 50	2 00	5 00	3,369 00
Truman & Schroeder, Manitowoc, Wis	20	15 00	2 00	05	03	04	03	04	1 25	2 25	1 00	2 50	3,168 50

Y 8.

TWO RIVERS HARBOR, WISCONSIN.

Original estimate	$265,588 80
Appropriated since	110,000 00
Leaving to be appropriated	155,588 80
Amount required for fiscal year 1878-'79	20,000 00

Repairs were made to 153 linear feet of the pile-revetment at the inner end of the north pier, which was damaged during a storm. The materials used were purchased in open market, and were as follows:

14.4 cords of stone, at $6	$86 40
35.7 cords of brush, at $2	71 40
	$157 80

Day-marks were erected on the sunken cribs at the end of each pier in April, in order to enable vessels entering the harbor to avoid the cribs.

After due advertising, a contract was signed June 18 with Messrs. Truman & Shroeder of Manitowoc, Wis., for building superstructures over the six cribs sunk in extension of the piers during the season of 1875. This work is now in progress, and will be completed during the present season. The work proposed for the year ending June 30, 1879, is the further extension of the piers as the appropriation will permit, sand-proof lining to the pile-piers, and dredging in the channel.

COMMERCIAL STATISTICS.

Name of harbor, Two Rivers, Wisconsin; collection-district, Milwaukee; nearest light-house, Twin River Point.

Arrival and departure of vessels during year ending December 31, 1876.

	Arrivals.			Departures.		
	Number.	Tonnage.	Crew.	Number.	Tonnage.	Crew.
Steamers	300	150,000	9,600	300	150,000	9,600
Sailing-vessels	90	9,000	500	90	9,000	500
Total	390	159,000	10,100	390	159,000	10,100

Exports for year ending December 31, 1876.

Lumber, ft., B. M	6,000,000	Hair, lbs	80,000
Laths, No	4,000,000	Wooden-ware, dozen	42,000
Pickets, No	75,000	Chairs, dozen	9,000
Ties, No	10,000	Grain, bushels	40,000
General merchandise, tons	3,200	Slabs, cords	3,000
Fish, pkgs	2,000	Wood, cords	4,000
Fish, fresh, lbs	450,000	Barrels, No	8,000
Hay, tons	300	Sundries, lbs	35,000
Leather, lbs	850,000	Furniture, packages	3,000

Imports for year ending December 31, 1876.

Bark, cords		Hides, green, bundles	10,000
Whitewood, cords		Salt, bbls	1,500
Lumber, ft., B. M	800,000	Flour, bbls	5,000
Shingles, No	500,000	Grain, bush	10,000
Hides, dry, No	10,000	Merchandise, tons	2,500

The above information was obtained from the Badger State and the Two Rivers Manufacturing Companies.

Money statement.

July 1, 1876, amount available	$1,012 65
Amount appropriated by act approved August 14, 1876	5,000 00
	6,012 65
July 1, 1877, amount expended during fiscal year	1,043 53
July 1, 1877, amount available	4,969 12
Amount (estimated) required for completion of existing project	155,588 80
Amount that can be profitably expended in fiscal year ending June 30, 1879	20,000 00

Abstract of bids received by Maj. Henry M. Robert, Corps of Engineers, May 19, 1877, for building superstructure on six cribs at Two Rivers Harbor, Wis.

Bidders' names and residences.	Pine timber, 12 by 12 inches, 8,600 linear feet, framed.	Oak timber, 12 by 12 inches 500 feet, board measure, framed.	Pine plank, 3 by 12 inches, 14,000 feet, board measure.	White oak or Northern pine piles, 300 linear feet.	Drift bolts, 1⅛ inches square, 14,000 pounds.	Screw bolts, nuts, and washers, 100 pounds.	Cut spikes, 7 inches, 350 pounds.	Wrought spikes, 9 inches, 100 pounds.	Stone, 240 cords.	Brush, 50 cords.	Laying plank, 14,000 feet, board measure.	Driving piles, 10.	Amount.
B. B. Locklin, Sheboygan, Wis	$0 26	$28 30	$11 00	$0 10	$0 04	$0 03½	$0 03	$0 04½	$6 00	$3 00	$3 00	$2 00	$4,666 65
Knapp & Gillen, Racine, Wis	24	40 00	10 00	15	03½	06	03	05	6 00	4 00	8 00	5 00	4,582 50
Hanson & Scove, Two Rivers, Wis	26	30 00	10 00	15	02 9/10	06	03¼	03½	6 00	2 00	2 00	4 00	4,428 87
Gagnon & Niquette, Two Rivers, Wis	22	16 00	9 00	8	03	03½	03	03¼	6 25	2 00	2 70	3 00	4,155 30
Charles Berner, Green Bay, Wis	20	30 00	9 00	6	03¼	05	04	05	5 50	3 00	2 00	5 00	3,906 00
Truman & Schroeder, Manitowoc, Wis	19	14 00	7 00	2	03	05	03	04	5 30	2 50	1 00	0 10	3,596 50

Y 9.

MANITOWOC HARBOR, WISCONSIN.

Original and subsequent estimates to get 18 feet water	$248,182 54
Appropriated since	211,500 00
Leaving to be appropriated	36,682 54
Amount required for the fiscal year 1878–'79	20 000 00

Superstructure was built over two cribs, sunk in extension of the piers, during the season of 1875. Owing to the late date of the appropriation, the work could not be let by the usual public advertising, but informal proposals were invited October 3 from bidders of previous years, and an agreement was concluded with Mr. H. Truman, of Manitowoc, under which the work was done.

General repairs to the old part of the piers were commenced in May last, and are yet in progress, the work being done by hired labor and purchase of materials in open market.

The operations contemplated during the fiscal year 1878–'79 are the extension of the piers as far as the appropriation will admit of, and dredging between the piers. The importance of completing this excellent harbor at the earliest practicable moment can hardly be overestimated.

The entire through commerce of the lakes bound from Buffalo to Milwaukee and Chicago is destitute of shelter on the east shore of this lake after leaving South Manitou Island Harbor, with the exception of that afforded by the harbor at Grand Haven, situated 150 miles to the southward and 50 miles directly out of the regular course. As the prevailing winds are westerly, masters of vessels usually seek the west shore, for the purpose of finding still water, striking it about Twin River Point, 10 miles northeast from Manitowoc Harbor. For a similar purpose the through commerce bound from Chicago and Milwaukee to Buffalo ordinarily hugs the west shore as far north as Twin River Point. After leaving Milwaukee, this harbor, 75 miles to the northward, affords the best shelter from violent storms, and from thence northward no harbor of refuge is available nearer than Bailey's Harbor, or North Bay, 70 to 75 miles distant. In addition, therefore, to the great benefit conferred upon the local traffic, this harbor should be completed as soon as possible for the refuge it affords to the general commerce of the lakes, and vessels plying to and from Green Bay and the ports on the western shore of Lake Michigan; and this importance should insure its maintenance forever. The extent to which it is sought in time of peril is an indication of the estimate placed upon its advantages, 150 vessels having sought shelter therein during a single storm. Were the piers extended to sufficient depth of water to admit of heavily-laden vessels entering it during severe gales, its value would be greatly enhanced.

COMMERCIAL STATISTICS.

Name of harbor, Manitowoc, Wis.; collection-district, Milwaukee; nearest light-house, Manitowoc.

Arrival and departure of vessels during year ending December 31, 1876.

	Arrivals.			Departures.		
	No.	Tonnage.	Crew.	No.	Tonnage.	Crew.
Steamers	404	2,996.78	11,938	404	2,745.04	12,000
Sailing-vessels	477	348.40	1,600	459	302.91	1,551
Total	887	3,045.18	13,538	863	3,047.95	13,551

Exports for year ending December 31, 1876.

Lumber	feet, b. m.	500,000	Ice	tons	20,000
Posts	number	25,000	Wood	cords	13,000
Flour	barrels	750,000	Wheat	bushels	200,000
Hay	tons	4,500	Merchandise	tons	cannot estimate.
Leather	packages	6,000	Bricks	number	250,000

Imports for year ending December 31, 1876.

Merchandise	tons	cannot estimate.	Iron	tons	1,700
Salt	barrels	4,000	Bark	cords	1,000
Coal	tons	1,000	Railroad-ties	number	20,000
Lumber	feet, b. m.	1,250,000	Vessels built	number	5
Shingles	number	2,700,000	Vessels repaired	number	30

The above information was obtained from George B. Burnett, deputy collector.

Money statement.

July 1, 1876, amount available	$1,143 48
Amount appropriated by act approved August 14, 1876	8,000 00
	9,143 48
July 1, 1877, amount expended during fiscal year	7,011 79
July 1, 1877, amount available	2,131 69
Amount (estimated) required for completion of existing project	36,682 54
Amount that can be profitably expended in fiscal year ending June 30, 1879	20,000 00

List of materials and labor used at Manitowoc Harbor, Wisconsin, during the fiscal year 1876–'77.

Articles.	Quantity.	Price.	Superstructure. Crib 42, north pier.	Superstructure. Crib 39, south pier.	Repairs of piers.
Pine timber, 12 by 12 inches, linear feet	3,953	$0 20	$404 20	$386 40	$157 83
Pine timber, 12 by 12 inches, feet board-measure	13,153	12 00			
Drift-bolts, pounds	6,998.2	3 to 3½	86 28	86 55	40 20
Screw-bolts and washers, do	1,319.3	4½ to 9	27 22	13 50	41 82
Wrought spikes, do	1 065	3½ to 3.07	2 80	2 45	32 61
Stone, cords	643.67	5 to 5 50	330 00	324 45	2,569 15
Plank, laid, feet board-measure	1,662	16 00	14 30	12 29	
Timber, framed, linear feet	3,953	09	181 89	173 88	
Brush, cords	127	2 00			254 00
Plank, feet board-measure	12,314	10 00			123 14
Washers, pounds	196	3 to 8			6 43
Paint, do	5	10			50
Labor					221 67
Total cost			1,046 69	1,059 52	3,447 35

Y 10.

SHEBOYGAN HARBOR, WISCONSIN.

Estimated cost of the improvement	$150,598 33
Appropriated to date	156,598 91

The decay of the old superstructure and the necessity for dredging, together with the fact that the lake-bed near the present mouth of the harbor has been raised by deposits from 4 to 6 feet since the work was commenced, render additional outlay necessary. The best policy would

be to run the piers out to 18-feet water in one season. But, as a sufficiently large appropriation for this could not be obtained, I propose to continue the repair-work on the old cribs (eighteen years old) commenced in 1875, and still in progress, doing the work, as heretofore, by hired labor, and purchase of materials in open market, as from the nature of the work no estimate can be made in advance on which to base a contract. The repairs are made by stripping off the old superstructure, putting on new timbers, refilling the cribs and intervals with brush and stone, and planking over all.

During the past fiscal year, superstructure was rebuilt over 137 linear feet of the north pier, three courses below and four courses above the water-surface, and over 413 linear feet of the south pier, from seven to eleven courses high. On the north pier, also, 110 linear feet of old superstructure has been partially removed, and other portions of the pier have been repaired.

The following table shows the amount of materials used and cost of same:

Articles.	Quantities.	Price.	Amount.
Timber .... feet, b. m..	114, 297	$12 50 / 12 75	$1, 449 16
Drift-bolts .... pounds..	6, 489	3¼ to 3¾	225 05
Drift-bolts, old, (reused) .... do....	4, 581	....	....
Tools, &c.	....	....	19 62
Labor	....	....	2, 280 52
Spikes, wrought .... pounds..	500	4¼	21 25
Spikes, cut .... do....	300	2¾	8 25
Bolts, screw .... do....	382	5	19 10
Repairs to scow	....	....	29 89
Total	....	....	4, 052 84

The work of repair is now temporarily suspended since June 1, but will be resumed about September 1. The amount asked for the fiscal year 1878–'79 will be used in continuing this repair-work and in dredging, if necessary.

COMMERCIAL STATISTICS.

Name of harbor, Sheboygan, Wis.; collection-district, Milwaukee, Wis.; nearest light-house, (on harbor pier,) Sheboygan, Wis.

Arrival and departure of vessels for year ending December 31, 1876.

	Arrivals.			Departures.		
	Number.	Tonnage.	Crew.	Number.	Tonnage.	Crew.
Steamers	836	493, 249	25, 614	836	493, 249	....
Sailing-vessels	330	23, 051	1, 190	325	23, 036	....
Total	1, 166	516, 300	26, 804	1, 161	516, 285	....

Exports for year ending December 31, 1876.

Wheat .... bushels..	725, 000	Flour .... barrels..	1, 400
Feed .... tons..	125	Potatoes .... bushels..	5, 500
Hay .... tons..	2, 100	Fish .... packages..	16, 400
General merchandise .... tons..	12, 400	Lime .... barrels..	20, 000
Brick .... number..	1, 100, 000	Stone .... cords..	700
Cattle .... heads..	700	Barrels .... number..	17, 000

Imports for year ending December 31, 1876.

Lumber ....feet. b. m..	9,205,000	Lath ....M..	1,550
Shingles ....M..	5,000	Posts ....number..	6,800
Coal ....tons..	12,200	Plaster-rock ....cords..	2,600
Merchandise .... tons..	10,300	Salt ....barrels..	12,400
Pickets ....number..	70,000	Bark....................cords..	5,000
Cement...............barrels..	1,000		

The above information was obtained from custom-house, steamboat-office, and various mill-owners.

Money statement.

July 1, 1876, amount available	$2,400 24
Amount appropriated by act approved August 14, 1876	6,000 00
	8,400 24
July 1, 1877, amount expended during fiscal year	5,351 00
July 1, 1877, amount available	3,049 24
Amount that can be profitably expended in fiscal year ending June 30, 1879, for repairs	6,000 00

Y 11.

PORT WASHINGTON HARBOR, WISCONSIN.

Original estimate	$154,527 17
Appropriated since	96,000 00
Leaving to be appropriated	58,527 17
Amount required for fiscal year 1878-'79	12,000 00

The change in the plan of this harbor recommended by me, July 6, 1876, (see report of Chief of Engineers, 1876, part II, page 379,) and approved by the Chief of Engineers, June 7, 1877, which doubles the area of the harbor, at an expense of $27,000 to the United States, does not provide for any increase in the estimate, which is ample for improving the harbor to as great an extent as at present seems justifiable.

During the past year the operations at this harbor consisted of repairs (made in July, 1876, and in May, 1877) to the embankment between the basin and the Sauk River, and to the pile revetment. These repairs were made necessary by damage caused during heavy floods in the spring of 1876. The work done last May prevented the usual breaking-in of the river during the June freshets. Repairs were also made on the United States dredge preparatory to work on this harbor and on the north pier. The proposed work during the present season is the excavating by the United States dredge of the basin in part, as detailed in my letter of July 5, 1876, to the Chief of Engineers, (published in Appendix W 11 of the report of the Chief of Engineers for 1876.) This will be commenced as soon as the dredge has finished the rock excavation at Ahnepee Harbor, which it is expected will be about September 1. It is proposed to continue the same work with the sum asked for the fiscal year 1878-'79.

The following table shows the quantities of materials used and the prices paid therefor. The work was done by hired labor and purchase of materials in open market:

Articles.	Quantities.	Price.	Amount.
Timber .... feet, board-measure..	1,776	$12.00 to 14.00	$324 19
Bolts .... pounds..	508½	3 to 5	21 49
Stone .... cords..	52	3 75 to 5 00	220 50
Brush .... do...	119 1-10	2 68 to 2 80	324 48
Labor	....	....	50 25
Total	....	....	640 91

COMMERCIAL STATISTICS.

Name of harbor, Port Washington, Wis.; collection-district, Milwaukee; nearest light-house, Port Washington.

Arrival and departure of vessels during the year ending December 31, 1876.

	Arrivals.			Departures.		
	No.	Tonnage.	Crew.	No.	Tonnage.	Crew.
Steamers	350	175,000	1,800	350	175,000	1,800
Sailing-vessels	460	23,300	1,600	460	23,300	1,600
Total	810	198,300	3,400	810	198,300	3,400

Exports for year ending December 31, 1876.

Stone .... cords..	300	Hay .... tons..	400
Wood .... cords..	2,000	Lime .... barrels..	9,000
Pork .... barrels..	350	Brick .... number..	1,000,000
Flour .... barrels..	2,000	Wheat .... bushels..	200,000
Cattle .... head..	400	Malt .... bushels..	40,000
Shooks .... packages..	4,000	Merchandise .... tons..	6,000
Barrels .... number..	5,000	Fish .... packages..	2,000

Imports for year ending December 31, 1876.

Salt .... barrels..	1,000	Iron .... tons..	600
Moulding-sand .... tons..	300	Coke .... tons..	300
Reapers .... number..	300	General merchandise... tons..	4,000
Seeders .... number..	400	Lumber. feet, board-measure..	10,000,000
Bark .... cords..	500	Lath .... number..	3,000,000
Coal .... tons..	700	Shingles .... number..	8,000,000
Land-plaster .... tons..	500		

This information was obtained from R. C. Kann.

Money statement.

July 1, 1876, amount available	$1,321 25
Amount appropriated by act approved August 14, 1876	8,000 00
	9,321 25
July 1, 1877, amount expended during fiscal year	1,776 07
July 1, 1877, amount available	7,545 18
Amount (estimated) required for completion of existing project	66,527 17
Amount that can be profitably expended in fiscal year ending June 30, 1879.	12,000 00

APPENDIX Z.

ANNUAL REPORT OF MAJOR D. C. HOUSTON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 11, 1877.

GENERAL: I have the honor to transmit herewith annual reports for the works in my charge for the fiscal year ending June 30, 1877.

I am, general, very respectfully, your obedient servant,

D. C. HOUSTON,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Z 1.

IMPROVEMENT OF MILWAUKEE HARBOR, WISCONSIN.

At the close of last season 560 feet of the stone superstructure of the north pier was completed, except pavement between the walls.

Five thousand dollars of the appropriation of August 14, 1876, was made available last fall. Part of this was applied to placing a pile and timber protection along the channel side of the north pier for a distance of 560 feet, (the extent of the stone superstructure,) to prevent collision by boats. The balance of the appropriation, $21,000, was made available April 21, 1877.

Owing to the meager appropriations and the dilapidated condition of the old superstructure, it was deemed advisable to limit the stone superstructure to the north pier and to apply the present appropriation to replacing the old superstructure of the south pier, 1,120 feet in length, with timber, and to put the north pier in as good condition as possible, waiting for an additional appropriation to complete the stone superstructure of the north pier. There has been rebuilt up to the close of the fiscal year, 800 running feet of the superstructure of the south pier for a height of 3½ feet. The funds available will be sufficient to complete the superstructure of the south pier, make other needed repairs and put in the pavement between the walls in the north pier. There will remain to be completed the stone superstructure on the north pier. The old cribs connecting the Government piers at the inner end of the harbor with private dock also need to be rebuilt above water.

I enclose reduced plat of soundings taken this season, which shows a good stage of water, so that no dredging will probably be necessary for some time. I enclose also a communication from Mr. W. H. Hearding, assistant engineer, giving statistics, &c. in regard to commerce.

Money statement.

July 1, 1876, amount available	$7,575 87	
Amount appropriated by act approved August 14, 1876	26,000 00	
		$33,575 87
July 1, 1877, amount expended during fiscal year	10,314 73	
July 1, 1877, outstanding liabilities	5,233 94	
		15,548 67
July 1, 1877, amount available		18,027 20
Amount (estimated) required for completion of existing project		30,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.		30,000 00

REPORT OF MR. W. H. HEARDING, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Milwaukee, July 9, 1877.

SIR: The accompanying plat of soundings taken at Milwaukee Harbor on May 21, 1877, which is respectfully submitted, shows a good navigable channel at a distance of 100 feet from the south pier and running parallel with the same for the whole length of the harbor entrance, the shallowest water being 16¼ feet when reduced to the plane of mean lake-level; or at the present stage, 17$\frac{6}{10}$ feet of water.

A comparison of these soundings with those taken in June, 1876, shows a deposit of about 6 inches of material to have been made upon the channel-bed between the piers.

The following information relative to the commerce of this port for the fiscal year ending June 30, 1877, was kindly furnished by John Nazro, esq., collector.

Summary of entrances and clearances.

	No.	Tonnage.	Men.
Entrances.			
Steamers*	2,748	2,228,270	71,305
Sailing-vessels*	4,351	575,141	21,825
Total	7,099	2,803,411	93,130
Clearances.			
Steamers †	2,759	2,247,168	70,538
Sailing-vessels†	4,468	576,919	22,172
Total	7,227	2,824,087	92,710
Clearances of American vessels to foreign ports ...schooners	37	11,878	306
Entrances of foreign vessels from foreign ports	15	5,258	210
Clearances of foreign vessels to foreign ports	20	7,064	249
Total entrances	7,114	2,808,669	93,340
Total clearances	7,284	2,843,029	93,265

* From American ports. † To American ports.

Vessels owned and documented at Milwaukee, Wisconsin, June 30, 1877.

	No.	Tons.
Sail, permanent enrollments	279	52,013.74
Steam, permanent enrollments	79	14,029.98
Sail, permanent registers	1	289.85
Sail, temporary registers	5	1,430.54
Steam, temporary registers	4	2,364.09
Steam, temporary enrollments	1	324.96
Total	369	70,453.16

ue collected, coin	$53,204 91
Revenue collected, currency	16,169 12
Total	69,374 03

Respectfully submitted by your obedient servant,

W. H. HEARDING,
Assistant Engineer.

Bvt. Col. D. C. HOUSTON,
Major of Engineers, U. S. A.

Z 2.

IMPROVEMENT OF RACINE HARBOR, WISCONSIN.

The appropriation of $8,000 was not made available until April 21, 1877, and is now being applied to replacing the old superstructure of the north pier.

A resurvey of the harbor was made this season for the purpose of showing what changes have taken place since 1870, and what work is required in future for the further improvement of the harbor.

I inclose tracing showing present condition of harbor, also report of Mr. W. H. Hearding, assistant engineer, giving results of survey and all information attainable in regard to the commerce of Racine and interests affected by the harbor.

From this report it will be seen that the principal trouble at this harbor is the heavy seas due to the funnel-shape of the entrance. This has been corrected in part since I have had charge of this work by extending the north pier eastward a distance of 150 feet beyond the south pier.

It appears that this extension has not been carried far enough to fully accomplish the purpose, and, although there is sufficient water at the harbor-entrance at present, I would respectfully recommend a further extension of the north pier of, for the present, 100 feet. This extension will soon become indispensable, on account of the shoaling caused by accretions.

This will, it is estimated, cost $14,000, which, added to my estimate of last year for repairs, &c., (not appropriated,) amounts to $21,000.

Money statement.

July 1, 1876, amount available	$244 57	
Amount appropriated by act approved August 14, 1876	8,000 00	
		$8,244 57
July 1, 1877, amount expended during fiscal year	463 95	
July 1, 1877, outstanding liabilities	1.637 30	
		2,101 25
July 1, 1877, amount available		6,143 32
Amount (estimated) required for completion of existing project		30,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		21,000 00

REPORT OF MR. W. H. HEARDING, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Milwaukee, June 18, 1877.

SIR: Having made the survey of Kenosha Harbor, I then proceeded to Racine, Wis., as directed by your instructions of April 25, and made a survey of the harbor-entrance at that point, Mr. J. P. Vose acting as my assistant.

This survey was completed on the 14th day of May. On the 28th of May I submitted to you a plat of my survey of Kenosha Harbor, with a report upon the same. Since that date, at such times as my other duties have not required my personal attention, I have made a plat of the harbor-entrance at Racine, which I have the honor herewith to submit. During the season of 1875 the channel was dredged to the full depth of 15 feet of water from the elevator to that depth of water in Lake Michigan. While the changes upon the lake-bed and adjacent shores are not so marked as at Kenosha, a comparison of the accompanying plat with that of the survey of 1870 showed quite a change to have been effected. On the north side the line of shore has not advanced materially, but the curve delineating the depth of 9 feet of water now embraces the line of 12 feet, as it existed in 1870, and the present line of 15 feet corresponds with that of 17½ feet in 1870.

The sand deposited in the channel between the piers averages more than one foot in thickness since dredging was done in 1875, (a period of two years.) I attribute the presence of this deposit chiefly to the infiltration of sand through the north pier. The abrading effect of the waves upon the lake-shore between Racine and Kenosha during the recent high stage of water has been a source of anxiety to owners of property fronting the lake. Many different methods have been adopted for shore-protection. The simplest and most effective method which I have seen is that used in front of the Kemper Hall property, which has proved completely successful. The Rev. Dr. Everhart, principal of that seminary, having tried the crib-jetty system, which failed, asked my advice upon the subject, and I furnished him with a plan and specifications upon the most economical principle of close piling, backed with brush filling and ballasted with bowlders of the largest size attainable.

I had visited the locality some years previous to his application, and knowing the character of the ground, thought this to be the best plan he could adopt. Some of the citizens of Racine are now protecting their property in a similar manner. A cross-section of this is shown upon the sheet.

The depth of water on the south side of the harbor-channel has increased since the year 1870, both to the east, or lakeward, and west, or shoreward, of the line of 12 feet, which line is now at about the same distance from shore as in 1870.

Within the past 4 years an extensive change has been made at the west or inner end of the outer reach of the river by the construction of wharves over an area which was formerly a bay of the river, and which served as a recess in which the force of the waves following up the channel from the lake was expended. The increased volume of wave from the lake through the deepening of the channel by dredging, combined with the narrowing up or curtailment of the space in which the wave-force was formerly broken, has had the effect of increasing the disturbance caused by storms in the next upper reaches of the river which carry a good depth of navigable water for the distance of more than a mile. The primary cause of this excessive disturbance is probably due to the funnel-shaped character of the channel. The distance from the present extremity of the north pier to a point in the lake which bears N. 45° E. from the east end of the south pier is 150 feet. If the north pier should be extended to this point, the effect of storms coming from the north to the northeast would be sensibly diminished. Should it be considered expedient to construct this extension, an estimate of its cost would be as follows:

ESTIMATE OF COST OF ONE CRIB OF DIMENSIONS 50′ × 30′ × 26½′.

For 25 cords of stone foundation.
For 216 cords of stone in crib.
For 7 cords of stone in interval.

For 248 cords of stone, at $11 per cord	$2,728 00
For 8,099 linear feet of 12″ × 12″ timber framed in work, at 36 cents	2,915 64
For 12,061 pounds of wrought-iron bolts, at 4 cents	482 44
For 16 cords of brush for interval, at $5	80 00
For 4,000 feet, board-measure, of 3-inch plank-decking, laid, at $18	72 00
For 200 pounds of iron spikes, at 5 cents	10 00
For 3 fender-piles, driven, at $10	30 00
For 50 linear feet of cap-timber to piles, (oak,) at 46 cents	23 00
For 60 pounds of screw-bolts, at 6 cents	3 60
	6,344 68
Add 10 per cent. for contingencies	634 46
Estimated cost of 1 crib	6,979 14
Total estimated cost of 3 cribs	20,937 42

The manufacturing interests of Racine are as extensive as those of any other city in the State of Wisconsin. As an accurate statistical account of the business done can only be obtained by visiting the several manufactories and business houses and from the books of these establishments extract such information, and as a considerable time would be consumed in collecting the same, I have thought that, for the purpose of showing the value of the articles manufactured, I would give the following statement, taken from the Racine Journal of date January 5, 1876, which is the latest compilation of facts obtained relative to the subject. It is stated by persons whose authority is reliable that the business done during 1876 was fully one-fourth more than in 1875, which is shown in a condensed form as follows: Thrashing-machines made, valuation $1,250,000; wagons and carriages, $1,000,000; wagon-trimmings, &c., $54,146; light hardware, $76,099; carriage-factories, $9,200; fanning-mills, $247,000; boiler and ma-

chine works, $65,000; silver-plate works, $20,000; building-material used, $552,041; marble, $12,000; baskets, $20,000; pumps, $51,500; sash and doors, &c., $110,000; wire manufactures, $15,000; tin and copper-ware, $16,000; business of meat-markets, $96,000; trunks and valises, $110,000; boots and shoes, $320,000; mittens, gloves, and furs, $89,000; leather, $594,000; harness manufactures, $16,000; woolens, $250,000; cotton-batting, $35,000; rope and twine, $54,000; furniture, $51,000; clothing, $42,000; millinery and dressmaking, $4,000; beer, $28,400; soda-water, $6,000; linseed-oil, $210,000; flour, $207,000; vinegar and pickles, $20,000; barrels, $10,500; crackers, $28,500; candy, $17,000; cigars, $50,200; cigar-boxes, $1,800; hay pressed, $23,000. Making a total in valuation for these articles of $5,805,786. The imports of coal were in 1876 30,000 tons; the imports of lumber, 28,000,000 feet, board-measure.

There are 41 vessels registered as belonging to Racine, the estimated value of which is $307,000.

The shipments from Racine over the Western Union Railroad during the year 1875 were as follows:

	Pounds.
Flax-seed	726,350
Flour	1,485,800
Salt	1,628,110
Shingles	1,640,800
Cedar posts	740,000
Bricks	740,000
Lumber	45,658,130
Lime	2,454,010
Agricultural implements	17,267,830
Coal	11,947,770
Miscellaneous	9,207,350
Water, lime, and cement	103,800
Total	93,699,150

Mr. J. I. Case's machine-shops cover 11 acres of ground.

During the year 164 new buildings were erected, in value $388,585.

Respectfully submitted.

W. H. HEARDING,
Assistant Engineer.

Brevet Colonel D. C. HOUSTON,
Major of Engineers, U. S. A.

Z 3.

IMPROVEMENT OF KENOSHA HARBOR, WISCONSIN.

Of the appropriation made August 14, 1876, for this harbor, but $150 was made available last season.

This was applied to minor repairs to piers. The balance, $7,850, was made available April 21, 1877.

This season the superstructure has been built over the two outer cribs of the north pier 100 feet in length, and the stone filling, which had settled, replaced. Some repairs have also been made to the section of the pier built in 1867.

A resurvey of the harbor was made this spring for the purpose of determining what changes have taken place since 1870 and what work is needed for the further improvement of the harbor. I inclose a tracing, showing present condition of the harbor; also report of Mr. W. H. Hearding, assistant engineer, giving result of survey, and all information attainable on the commerce of the place.

From this report it will be seen that about $7,000 are required to put the existing works in good order, and that about 10,000 cubic yards of dredging are necessary. The funds available will suffice for the dredging, leaving $7,000, my estimate of last year, needed to put works in good order.

It further appears, as has been heretofore reported, that it will be neces-

sary to extend the piers to protect the channel, owing to the constant shoaling due to accretions north of the piers. Mr. Hearding estimates that in the next twenty years the north pier should be extended 400 feet and the south pier 500 feet, at an estimated cost of not less than $80,000, an average of $4,000 per annum. This is, to a great extent, conjectural, but it is evident that one or both of the piers will require extension from time to time. I would, therefore, recommend an appropriation for the extension of the north pier 100 feet.

The amount (estimated) required for completion of existing project includes the probable pier-extension for twenty years, as above stated, but does not include the repairs which may become necessary in the mean time.

Periodical appropriations will be needed for pier-extension, repairs, and dredging.

Money statement.

July 1, 1876, amount available	$361 83	
Amount appropriated by act approved August 14, 1876	8,000 00	
		$8,361 83
July 1, 1877, amount expended during fiscal year	874 72	
July 1, 1877, outstanding liabilities	3,415 86	
		4,290 58
July 1, 1877, amount available		4,071 25
Amount (estimated) required for completion of existing project		80,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		17,000 00

REPORT OF MR. W. H. HEARDING, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Milwaukee, May 28, 1877.

SIR: In obedience to your orders of the 25th ultimo, directing me to make resurveys of the harbors of Kenosha and Racine, Wis., I have the honor to state that as soon as I had made the necessary preparations I proceeded on the 27th ultimo to carry out your instructions, first in reference to Kenosha, taking with me, as an assistant, Mr. J. P. Vose.

The prevalence of a northeast wind retarded operations somewhat, by reason of which the survey was not completed until the evening of Saturday, the 5th instant.

By comparing the accompanying map with the plat of survey made in 1870, it will be seen that important changes have been made at this harbor, the shore accretion on the north of the harbor channel having formed eastward to a distance of 140 feet.

To obtain at once a clearer perception of the quantity of drifted material which has accumulated than will be readily observed, except by a close scrutiny of the plan, I have selected 3 sections, AB, CD, EF, from the lines of levels taken.

By referring to section EF, it will be seen that at a mean distance of 30 feet lakeward from the shore-line of 1870 the accumulation of sand and gravel has been deposited to an average thickness of $7\frac{5}{10}$ feet above mean lake level for the whole length of the sectionn orth of the pier; and, furthermore, where there was a depth of 7 feet of water in 1870 there is now a thickness of sand and gravel above mean lake level of 7 feet, equal to a deposit of 14 feet of drifted material. This section also shows that the accretion is nearly on a level with the top of the highest portion of the pier.

The sections AB and CD show the relative heights of the pier and adjacent accretions north.

On section CD, at a distance of 80 feet from the pier, the height of the drift is $7\frac{8}{10}$ feet above the top of the pier.

Section AB shows the effect of the action of the water back of the pier and adjacent accretions.

During the prevalence of northerly winds some of the light dry sand is carried from the banks into the channel.

The changes in the lake bed are not less marked than those on shore, a bank having formed which runs parallel with the shore-line, carrying from 6 to 8 feet of water upon its crest. In 1870 there was an average depth of 15 feet of water where the line which delineates the outer 9-feet curve now runs.

The line of 12 feet of water would overlap the present extremity of the north pier, but for the effect produced upon the lake-bed by the breaking of the waves upon the

pier-head, the sand is removed by the agitation of the water, and is carried during north-east storms across or in front of the channel, and is there deposited. I assume this theory to be correct, for I can in no other way account for the shoal which is forming to the southeastward of the south pier, and which threatens to become a serious obstruction to the navigation of the harbor channel.

During the months of June and July, 1875, the channel was dredged to the full depth of 15 feet for its entire length from the basin to the deep water of Lake Michigan.

The authorities of the city of Kenosha have lately authorized the expenditure of a small sum of money for dredging-purposes at the harbor entrance.

The washing away of the banks to the northward of the inner or west end of the north pier has continued in its operation, and the owners of the property facing the east side of the basin should take measures to arrest this action.

The line of wharves inside the harbor basin has been considerably increased within the past two years, and while commenting upon this fact, it may be proper to direct your attention to the increased size and position of that which covers the outlet of Pike Creek, upon which a flouring-mill has been built. Should the commerce of the place ever require the utilization of the river banks to the westward of the basin, the removal of this wharf would become a matter of necessity to the free ingress and egress of vessels. The section of the north pier termed the high section, which is 185 feet in length, is becoming very much dilapidated, and the superstructure should be removed and replaced with new work. The section immediately east of this, built in 1858, also requires slight repairs.

A section of the south pier immediately east of the warehouse is tilted toward the channel, caused probably by the work of the dredge under the city authorities.

Before endeavoring to give an estimate in detail of the cost of putting the existing works in thorough order and the probable work required in the future, as directed by your order, it may be well to note the rate of advance made by the shore-line through accretion, taking as a basis for such estimate the increased accumulation of drift since the survey was made in May, 1870. The growth of the beach outward from this cause has been at the rate of 19 feet per annum.

The distance from the present intersection of the shore-line with the north side of the pier to the outer extremity of the same is 410 feet. At such a continued rate the time occupied in forming the beach to the end of the pier would be 21½ years, but as an estimate of the distance to which the line of 12 feet of water would be carried during such a period can only be conjectural, I can only assume that it will or may be proportional to the outgrowth of the beach.

To insure a navigable depth of water between the piers for such a length of time it may be safely stated that the north pier should be extended 400 feet into the lake upon a due east line, and the south pier to a probable distance of 500 feet. The cribs for the north-pier extension to be 24 feet in width, and those of the south 20 feet wide. The north-pier extension to be built first, or until the effect of such extension upon the lake-bed on the line of the south pier is determined.

Taking the present prices of materials and labor as a basis of cost, an estimate for the same would be as follows, viz:

For 1 crib of 50′ × 24′ × 22½′, set upon a stone foundation.

For 20 cords of stone foundation.
For 147 cords of stone in crib.
For 5 cords of stone in interval.

For 172 cords of stone in bowlders, @ $10.50	$1,806 00
For 6,121 linear feet of pine timber, @ 22 cents	1,346 62
For 9,859 pounds of iron bolts, @ 4 cents	394 36
For 3,300 feet (B. M.) of 3-inch plank, laid, @ $18	59 40
For 200 pounds of iron spikes, @ 5 cents	10 00
For 12 cords of brush, @ $5	60 00
For framing 6,121 linear feet of timber, @ 13 cents	795 73
For 3 fender-piles, driven, @ $10	30 00
For 50 feet cap of framed oak, 12 inches by 12 inches, @ 46 cents	23 00
For 60 pounds of screw-bolts, @ 6 cents	3 60
	4,528 71
Add 10 per cent. for contingent expenses	452 87
Total cost of one crib	4,981 58
Total estimate of cost of 8 cribs = 400′ pier	39,852 64

The cost of extending the south pier to a distance of 500 feet would approximate as follows:

Cost of 1 *crib* 50′ × 20′ × 18½′.

For 18 cords of bowlder-stone for foundation.
For 100 cords of bowlder-stone in crib.
For 5 cords of bowlder-stone in interval.

For 123 cords of stone, @ $10.50	$1,291 50
For 4,313 linear feet of pine timber, @ 22 cents	948 86
For 6,393 pounds of iron bolts, @ 4 cents	255 72
For 2,700 feet of 3-inch plank, laid, @ 18 cents	48 60
For 175 pounds of iron spikes, @ 5 cents	8 75
For 10 cords of brush, (in interval,) @ $5	50 00
For framing 4,313 linear feet of pine timber, @ 13 cents	560 69
For 3 fender-piles, driven, @ $10	30 00
For 50 feet cap-timber, oak, for piles, @ 46 cents	23 00
For 60 pounds of screw-bolts, 6 cents	3 60
	3,220 72
Add 10 per cent for contingent expenses	322 07
Cost of crib	3,542 79
Total cost of 10 cribs for south pier	35,427 90
Total cost of 8 cribs for north pier	39,852 64
Total estimate of cost of pier extension	75,280 54

The cost of putting the existing works in good order would be as follows, as nearly as can be estimated:

For raising the superstructure 2 feet in height over the section of north pier at its west end 362 feet in length.

For 1,824 linear feet of pine timber, framed in work, @ 32 cents.	$583 68
For 3,403 pounds of iron bolts, @ 4 cents	136 12
For 80 cords of stone ballast, @ $10.50	840 00
Total	1,559 80
For sheet-piling in rear of above section, 362 feet, @ $4 per running foot	1,448 00

For cutting down and replacing high section 185 feet in length by 9 feet in height.

For cutting down old work, @ $1 per foot	$185 00
For 6,986 linear feet of pine timber, framed in work, @ 32 cents	2,235 52
For 11,262 pounds of iron bolts, @ 4 cents	450 48
	2,871 00

RECAPITULATION.

For raising superstructure, west end of north pier	$1,559 80
For sheet-piling in rear of above section	1,448 00
For cutting down and rebuilding high section	2,871 00
	5,878 80
Add 10 per cent. for contingent expenses	587 88
	6,466 68

Besides this, dredging to the extent of 10,000 cubic yards at the harbor entrance is required, which, at 25 cents per yard, would cost $2,500.

I have not included this item in the estimate of necessary repairs, for the reason that the benefit to be derived thereby would be only temporary. The services of a dredging-machine will be required continually unless means are provided for extending the piers. This method of maintaining a channel of navigable water is unsatisfactory, for the reason that one storm will frequently fill up a trench which has taken an efficient dredging-machine two or three weeks to excavate, and, also, the masters of vessels, even when in stress of weather, will prefer to encounter risk outside than to attempt to enter an uncertain channel.

The commerce of Kenosha has felt the depression which has pervaded the whole country for the past two years, yet by the following statement, which I obtained from the deputy collector, and from the general tone of feeling which prevails, I assume that the prospects of an increase in trade for Kenosha are not less bright than in other towns of similar size.

The exports for the past year were 40,000 bushels of oats, 5,000 bushels of flax-seed, 150,000 pounds of wool, 50,000 pounds of hides, 560,000 pounds of fish; other produce to the value of $100,000. The country in the neighborhood of Kenosha is chiefly devoted to dairy-farming. On many estates as many as from 100 to 400 milch-cows are kept. I could not obtain the quantity of butter made, but should estimate it at 200 tons annually.

Quite extensive manufactures of agricultural implements are in active operation. Thirty thousand bushels of malt are made annually.

The principal imports for manufacturing purposes during the year were 6,500 tons of coal, 5,500 cords of wood, 3,000 barrels of salt, 2,000 cords of tan-bark, 1,200 tons of pig-iron, 1,225 tons of bar-iron, 11,650,000 feet (board measure) of pine lumber, 750,000 feet (board measure) of hard-wood lumber, 200 cords of stone, 260 barrels of oil and turpentine, 156,000 pounds of white lead.

It is expected that the Kenosha and Rockford Railroad will extend the road from its present terminus, west of the city, down to the basin, which will facilitate the business of the place.

Respectfully submitted by your obedient servant,

W. H. HEARDING,
Assistant Engineer.

Brevet Colonel D. C. HOUSTON,
Major of Engineers, U. S. A.

Z 4.

IMPROVEMENT OF FOX AND WISCONSIN RIVERS.

At the commencement of the fiscal year the principal works in progress were as follows:

Construction of locks of stone masonry at Grand River, Princeton, White River, Berlin; Eureka, second lock at Appleton; Upper Combined lock, Little Chute; third and fourth locks, Kaukauna; dams at the Cedars, Little Chute Kaukauna, Rapid Croche, and Little Kaukauna. Two dredges were also at work on the Upper Fox.

It was expected to complete all of the works above mentioned last season, and also to excavate canals and construct dams at all the locks on the Upper Fox, but the delay in making appropriations retarded operations, and when the appropriation was made, August 14, 1876, the total amount was not allowed to be expended.

It was not until September 14, 1876, that the allotment of $120,000 was made. This rendered it necessary to limit the work to what was deemed indispensably necessary. The main masonry-walls of the locks above mentioned, except coping, were completed last season. At Eureka lock and Upper Combined lock the coping was finished. The dams at the Cedars, Little Chute, and Little Kaukauna, except earth-filling at the first two, and some stone riprapping at the latter, were nearly finished. The dam at Rapid Croche, except a gap of about 75 feet, and a dam at Kaukauna, except a break of about 125 feet, and filling above dam, were nearly finished. On the 21st of April, 1877, I was notified that the balance of the appropriation of 1876, $150,000, had been made available, and operations were at once resumed on the Lower Fox with a view to opening the line for navigation, completing all new work and putting the old locks in working order.

The line was open for navigation, as far as locks are concerned, on June 1, from Portage City to Green Bay.

The work done this season has been as follows:

Menasha lock, (old.)—This lock has been pumped out; a new upper miter-sill put in; a portion of lock-chamber replanked; lower wing-walls repaired, and lock put in good working order. The canal-banks were repaired.

Appleton second lock, (*new.*)—The filling behind lock-walls has been completed. The foot of lower wing-walls protected by stone facing; coping for lock has been quarried, and mostly dressed, and 117 linear feet delivered at lock.

Cedars Dam, (*new.*)—Ninety-one cubic yards of slope-wall have been laid, and 110 yards of earth-filling placed in rear of same; 2,800 yards of clay and gravel filling have been placed above dam.

Combined locks at Little Chute, (*new.*)—The dry stone and slope walls have been completed and the filling behind the lock-walls; a small amount of coping to be laid will complete these locks.

Kaukauna Dam, (*new.*)—Materials for closing break in this dam have been procurred and the north abutment of masonry nearly completed.

Kaukauna third and fourth locks, (*new.*)—The filling behind lock-walls is nearly completed, also the upper wing-walls. The coping is being quarried at quarry near at hand.

Rapid Croche Dam, (*new.*)—This dam is about finished, except clay and gravel filling above dam.

Little Kaukauna Dam, (*new.*)—One hundred and sixty cubic yards of riprapping have been placed below the dam, and stone quarried for coping to abutments delivered.

Depere lock, (*old.*)—This lock has been thoroughly repaired; new gates put in; new wing-walls, and portions of the walls, rebuilt.

Eureka Dam, (*new.*)—The construction of permanent dam at this point has been commenced.

Grand River lock, (*new.*)—The construction of wing-walls has been commenced at this point.

General repairs have been made to all the old works, such as putting in new gates, raising canal-banks, stopping leaks, &c., incidental to opening navigation. New gates are being constructed to replace old gates where necessary. A dredge is at work on the Lower Fox removing obstructions, improving channels, and digging gravel for filling above dams. One dredge is at work excavating canal at Berlin, and another at Grand River Canal.

It is expected, early this season, to entirely complete all new work on the Lower Fox, and to put the line in the best working order practicable; to complete the locks at Berlin, White River, Princeton, and Grand River, Upper Fox; to excavate the canals at those places for a width of 50 feet; construct permanent dam at Eureka, and temporary dams at the other locks on the Upper Fox.

The coping on the four locks above mentioned may not be laid this season, but it will probably be got out at quarry on Lower Fox, and transported after completion of dams on Upper Fox.

The total new work expected to be completed this season will be, 10 locks of stone masonry; 1 dam of stone masonry; 5 dams of timber cribs filled with stone; 1 dam of timber flooring and stone abutments, with navigable pass at Eureka lock; 5 temporary dams, which will serve the purpose of diverting the river through new cuts and over permanent dams on Upper Fox; the excavation, 75 feet wide and 6 feet deep, of Portage Canal, $2\frac{1}{4}$ miles long, and revetting the banks of same with pile and timber docking; excavation of canal at Eureka lock, 100 feet wide, 5 feet deep, and 1,450 feet long; at Berlin, 50 feet wide, 5 feet deep, and 2,400 feet long; at White River, 50 feet wide, 5 feet deep, and 1,150 feet long; at Princeton, 50 feet wide, 5 feet deep, and 1,000 feet long; at Grand River, 50 feet wide, 5 feet deep, and 2,000 feet long.

The old locks will all have been put in as good condition as they will admit; several of them are in excellent condition; new gates have been

put in where required. A large amount of dredging has been done in the canals and river; canal-banks have been raised and strengthened, waste-weirs put in, and a large amount of miscellaneous work necessary to maintain the old work.

There are now on the Lower Fox 6 masonry locks; 5 of the old locks are in good condition, and should last several years. There remain 7 locks which should be replaced or thoroughly repaired; new locks can be constructed alongside the old without interrupting navigation. The dam at Depere should be rebuilt, but it is believed that it should be done by the water-power interests at that place, if not wholly, in part at least. It is probable that some satisfactory arrangement may be made.

The lower dam at Appleton will probably need to be rebuilt before long. On the Upper Fox a new guard-lock should be built as soon as funds are provided; the lock at Governor's Bend will have to be rebuilt; permanent dams constructed at Grand River, Princeton, White River, and Berlin. After this work is done, and while in progress, an immense amount of dredging will be required on the Upper Fox, to deepen, widen, and shorten the channel.

The work after this season should show continuous improvement in the navigation of the Fox River, and will be the result of the work which has already been done.

On the Wisconsin River nothing has been done since 1875, the funds available being all required for operations on the Fox, where the work was of a more expensive character. I made an examination of a portion of the Wisconsin River on June 8, on the steamer Winneconne, drawing 27 inches. For a distance of 12 miles below Portage City, where the dams are continuous and the work approximates completion, we had no difficulty, but below that point we were unable to proceed. *This section includes some of the worst places in the river.*

Appended to this report is a list of soundings taken in the channel for 12 miles below Portage City. It will be observed that there are only 3 soundings less than 4 feet, the lowest being 3 feet on an old timber dam. The stage of water was very low, 0.4 of a foot above low water of 1867. No work has been done on the river since 1875, and a few of the dams have settled so as to divert a portion of the current from the channel. Had the dams been maintained *as they could have been at small expense*, I am satisfied that the channel would have improved still more. This examination has confirmed me in the views heretofore expressed as to the practicability of the system of improvement adopted, and it will not be necessary to expend any more money to determine this point.

Only a small amount can be spared in any case, so that no immediate benefit could be obtained. Some repairs are needed, but it will cost more to organize a special force for this purpose than to make more extensive repairs when funds are provided to go on with the work and a large force organized. It is useless to attempt further operations on the Wisconsin without sufficient funds to carry on the work to advantage.

The funds now available will all be needed to carry out the project of operations on the Fox River.

It is important that funds be provided to maintain the dams already built, and to go on with the improvement of the river.

The cost of maintaining these dams would be inconsiderable if attended to in time; a small steamer with two scows and a small party could keep up the dams the entire length of the river.

The method of improvement adopted has been pronounced impracticable by Maj. G. K. Warren, of the Corps of Engineers, in his report of

November 26, 1875. I do not deem it necessary to discuss the matter, as I consider the question practically solved in favor of the method. Much experience has been gained, especially in 1875, the last year of the work, and much more is to be learned to secure the best results.

At the same time I made the examination above mentioned on the Wisconsin, I took the boat down to a few miles below Montello, on the Fox River, a distance of 33 miles.

From Portage to Montello the system of slack-water has been established, and an immense amount of dredging has been done in former years. The navigation of the Wisconsin for the distance gone is decidedly better than that of this portion of the Upper Fox, and I am satisfied that by the method pursued the Wisconsin River channel can be made fully as good, if not better, than the Upper Fox admits of at any reasonable expense. It seems to me that, all things considered, the true policy (even if a canal should ultimately be made along the Wisconsin River, and in view of the cost of improving the Upper Fox) is to continue the improvement of the Wisconsin River channel to the fullest extent it admits of. In this way, at least partial benefit will be more speedily secured.

I concur with Major Warren in his recommendation that an immediate and thorough survey be made for determining the best route for a canal along the valley of the Wisconsin River.

The object of this work is to establish a water-route from the Upper Mississippi to the lakes, by which transportation will be cheapened.

The arguments on this subject are fully given in the report of Maj. G. K. Warren, Corps of Engineers, Report of Chief of Engineers for 1868, page 357, and in the report of the Select Committee on Transportation-Routes to the Seaboard, United States Senate, 1874.

I transmit herewith reports of Capt. G. J. Lydecker and First Lieut. F. A. Hinman, Corps of Engineers, United States Army.

The amount of tolls collected during the year ending June 30, 1877, is $653.36; required to be reported annually by act of Congress approved July 7, 1870.

Navigation was interrupted most of the year by the building of locks.

Money statement.

July 1, 1876, amount available	$159,442 17	
Amount appropriated by Act approved August 14, 1876	270,000 00	
		$429,442 17
July 1, 1877, amount expended during fiscal year	269,448 68	
July 1, 1877, outstanding liabilities	14,685 48	
		284,134 16
July 1, 1877, amount available		145,308 01
Amount (estimated) required for completion of existing project		2,975,663 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		750,000 00

FOX RIVER.

REPORT OF CAPTAIN G. J. LYDECKER, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 7, 1877.

SIR: I have the honor to submit the following report of operations on the improvement of that portion of the Fox River which was in my charge during part of the fiscal year ending June 30, 1877.

The report covers operations from the beginning of the year until the end of April, 1877, at which time I was relieved from duty under your orders.

The main object in view, at the opening of the season, was the completion of the new locks on the Upper Fox, and of the new locks and dams on the Lower Fox. These had all been commenced during the preceding fiscal year, and at the beginning of the present year were in various stages of progress, some showing but a bare beginning, while others were well on toward completion, as explained in detail hereafter.

On the Lower Fox it was especially desired to complete all works, so far as necessary to re-open navigation from Green Bay to Lake Winnebago, early in the fall.

From various causes, the principal of which were a lack of sufficient funds and the continuance of a very unusually high stage of water throughout the season, we were unable to accomplish all that had been expected; but, considering the obstacles in the way, the amount of work done is a very satisfactory showing. The masonry of all the locks was completed, except coping; the new dams, on the Lower Fox, except that at Rapid Croche, were finished with the exception of placing a backing of clay and gravel, which is designed to give them increased stability. The little Kaukauna dam was the only one at which any considerable amount of this backing was placed.

Navigation of the Lower Fox was finally re-established early in November.

The following outline of operations at each point is respectfully submitted:

1. GRAND RIVER LOCK.

The work of building the new lock at Grand River had been suspended in March, 1876, at which time the pile and timber work of foundations had been completed. Operations were not resumed until the middle of July following, the site having been entirely under water during that period. The pit was then pumped out, and by the beginning of August everything was ready for laying concrete of foundations.

This was completed August 12, and by the end of the month the flooring and miter-sill platform had been finished. The masonry of walls, coping excepted, was laid from August 22 to October 14. In the mean time, while this was in progress, the river suddenly rose to freshet stage, (September 5,) flooded the lock-site, and put a stop to all work until September 26, a period of three weeks.

After completing the masonry of walls, the gates, which had been built, were stored with their irons, valves, &c., and it became necessary to suspend all further operations on this work owing to lack of available funds.

The chamber-walls of this lock are 14.5 feet high, exclusive of coping; their thickness at bottom is 7.5 feet.

Principal items of material and labor in the work at time of suspension were as follows:

9,427 cubic yards excavation for lock-pit.
513 (7,778 linear feet) bearing-piles in foundations.
117,520 feet, B. M., timber in foundations, platforms, &c.
47,646 feet, B. M., plank flooring, sheet-piling, &c.
213.1 cubic yards concrete foundations.
1,657.37 cubic yards masonry in walls.
8,671 pounds iron, bolts, &c.

In order to complete this work, the upper slope-walls and lower wings have yet to be built; stone for coping obtained and laid; earth filling embanked against walls; gates and valves to be hung, their maneuvering apparatus attached, &c.

2. PRINCETON LOCK.

The foundations of this lock had just been completed at the opening of the fiscal year, at which time the work of placing flooring and building miter-sill platform was in progress. The masonry of lock-walls was commenced July 10, and finished August 12, exclusive of coping. The construction of lower wing-walls was then commenced, and carried to a height of 6 feet, the excavation for slope-walls above the lock was also made, but owing to lack of funds, and the requirement of limiting expenditures to work absolutely necessary, all operations were suspended here on the 25th of August.

In the mean time the gates had been put together and set up, but not secured in place. The chamber-walls of this lock are 13 feet high, exclusive of coping; their thickness at bottom is 6.5 feet.

In addition to building gates, valves, &c., the following are the principal items in the construction of this work:

8,051 cubic yards excavation for lock-pit.
501 (7,960 linear feet) bearing piles in foundation.
106,316 feet, B. M., timber in foundations, platform, &c.
43,168 feet, B. M., plank in flooring, sheet-piling, &c.
213.6 cubic yards concrete in foundations.
1,315.58 cubic yards masonry in walls.
8,362 pounds iron, bolts, &c.
5,871 cubic yards embankment against walls.

In order to complete this work the wing and slope walls have to be finished, the coping to be obtained and laid, the embankment behind walls finished, and the usual auxiliary work, such as hanging gates, valves, &c., required for putting the lock in working order.

3. WHITE RIVER LOCK.

The masonry of lock-walls, except coping, had been completed at the beginning of the fiscal year.

During the months of July and August the lower wing-walls and upper slope-walls were built; lock-gates put together and set up, though the hangings were not attached; platform-valves and their maneuvering apparatus were placed. All operations on this work were then suspended. The chamber-walls of this lock are 15 feet high, exclusive of coping. Their thickness at bottom is 7.5 feet.

In addition to work on wing-walls, gates, valves, &c., the following are the principal items of labor and materials applied to the construction of this lock:

12,705 cubic yards excavation for lock-pit.
513 (8,940 linear feet) bearing-piles in foundations.
114,674 feet, B. M., timber in foundation, platform, &c.
48,069 feet, B. M., plank in flooring, sheet-pilings, &c.
210 cubic yards concrete in foundations.
1,653.89 cubic yards masonry in walls.
8,252 pounds iron, bolts, &c.

The coping of lock-walls remains to be obtained; also the earth-embankment in rear of walls is to be placed before the work is finished.

4. BERLIN LOCK.

Work on this lock had been commenced in July, 1875, and continued to December 16, 1875, at which time the timber-work of foundations had been completed and operations suspended.

They were not resumed until September 13, 1876, as it was not deemed advisable to do anything further on the work until it should be established that there would be sufficient money to do so without interfering with the completion of more important works. It was finally decided that this could be accomplished by changing the character of face-masonry by which we were enabled to utilize small stone and material which had been left over at the other works. The original project for this, as for the other new works, contemplated a facing of cut stone laid in regular courses of not less than 14 inches rise, but in the modified plan small stone, hammered to a rectangular shape, were used below the water-line, the larger cut stone which were already on hand being then sufficient to complete the work above this line. Accordingly, the lock-pit was pumped out and cleaned up during the latter part of September, and the concrete for foundations put in by October 11. The flooring was then placed, miter-sill platform built, and masonry of lock-walls commenced October 19.

The masonry (except coping) was completed November 11, when operations were suspended.

The chamber-walls of this lock are 13 feet high, exclusive of coping; their thickness at bottom 6.5 feet.

The following are the principal items of labor and material applied to the construction of this work:

8,270 cubic yards excavation for lock-pit.
499 (7,644 linear feet) bearing-piles in foundations.
107,904 feet, B. M., timber in foundations, platforms, &c.
41,468 feet, B. M., plank in flooring, sheet-piling, &c.
211 cubic yards concrete in foundations.
1,301.48 cubic yards masonry in walls.
8,133.7 pounds iron, bolts, &c.

To complete the work, the wing and slope walls have to be built; coping obtained and laid; embankment placed against walls; gates, valves, maneuvering apparatus, &c., built and put in place.

5. EUREKA LOCK.

All the masonry of this lock, including the coping, wing-walls, and slope-walls, had been completed when the fiscal year opened. The gates were hung, valves constructed and put in place, and earth-embankment filled against lock-walls during July and August. At the end of August operations were temporarily suspended while awaiting instructions with reference to further expenditures. Authority to complete the work having been given, the capstans and attachments for working gates were built, maneu-

vering-rods, &c., applied to valves, and the lock opened to navigation by the end of September.

The chamber-walls are 15.5 feet high, their thickness at base being 7 feet.

The following are the principal items in this lock:

1,000 cubic yards excavation for lock-pit.
410 (7,380 linear feet) bearing piles in foundations.
120,997 feet, B. M., timber in foundations, platforms, &c
53,800 feet, B. M., plank in flooring, sheet-piling, &c.
158.5 cubic yards concrete in foundations.
1,496 cubic yards masonry in walls.
247.75 cubic yards dry-stone wall in wings, &c.
25,003 pounds iron, bolts, &c., including castings.

6. APPLETON SECOND LOCK.

On this work the masonry of walls had just been commenced as the fiscal year opened, and was completed October 7.

In the meantime the valve-platforms and miter-sills were built, and during October the upper slope-walls were built, and a flooring of concrete was laid. Temporary arrangements for working gates and valves were made, so as to put the lock in working order by the first of November.

About 3,000 cubic yards of earth-filling was embanked against the lock-walls.

The height of chamber-walls to bed of coping is 18.2 feet above the floor of lock, their thickness at that level being 9 feet. Their foundations, of concrete, are carried about 6 feet on an average below that level.

In addition to work on gates and valves, the following are the principal items applied to the construction of this lock:

9,471 cubic yards excavation, (tearing out old lock, &c.)
3,269 cubic yards embankment against walls.
17,501 feet, B. M., timber in platforms, &c.
3,820 feet, B. M., plank in platforms, &c.
3,615 cubic yards masonry in walls and foundations.
121 cubic yards dry-stone wall.
100 cubic yards concrete flooring.
2,625 square feet flagging under valve-platform and in tail bay.

The coping of walls, construction of lower wing-walls, permanent gate-hangings, and maneuvering apparatus are yet required to complete the work.

7. LITTLE CHUTE (UPPER COMBINED) LOCK.

Masonry work which was in progress at the beginning of the year was continued until September 12, when the walls were complete, except coping. This was subsequently placed in October. In the mean time the flooring was completed, valve-platforms built, temporary arrangements made for hanging and working gates and valves, and about 2,500 cubic yards of earth embanked against walls. The lock was then opened for navigation early in November.

The height of chamber-walls from floor to top of coping is 18.68 feet, the thickness at floor-line being 8.75 feet. The foundations, of concrete, extend 3 feet below this level.

In addition to work on gates, valves, &c., the principal items applied to the construction of this lock are as follows:

7,109.26 cubic yards excavation.
2,549.4 cubic yards embankment.
60,644.64 feet, B. M., timber, &c.
36,686 feet, B. M., plank.
748.52 cubic yards concrete in foundations.
1,777.55 cubic yards masonry in walls.
4,911.4 pounds iron, bolts, &c.

The construction of upper slope-walls, permanent gate-hangings, &c., and additional filling against walls are required to complete the work.

8. KAUKAUNA THIRD LOCK.

During the month of July the bed-rock was leveled off, and preparations made for commencing masonry of walls. The walls were commenced July 12, and completed, except coping, October 7.

Subsequently, the valve-platforms were built, miter-sills placed, temporary arrangements for working the gates and valves made; about 1,000 cubic yards of earth-embanked against head-walls of lock, so as to admit of navigation being opened early in November.

The chamber-walls of this lock are on a foundation of solid rock, 17.53 feet high to bed of coping, and 8 feet thick at bottom.

The principal items in the construction of this lock are as follows:

5,576 cubic yards excavation, (tearing out old lock.)
16,547 feet, B. M., timber in platforms and miter-sills.
7,034 feet, B. M., plank in platforms.
1,798.58 cubic yards masonry in walls.

In order to complete the lock, coping must be obtained and laid; slope and wing walls constructed; permanent gate-hangings attached, &c., and earth-filling embanked against walls.

9. KAUKAUNA, FOURTH LOCK.

The masonry, having been started about the close of the preceding fiscal year, was completed September 16, except coping of walls. After that the valve-platforms were built, miter-sills placed, and other temporary arrangements made, as described in the preceding paragraph for the third lock, so as to open navigation early in November.

The following are the principal items in the construction of this work:

6,051.46 cubic yards excavation.
15,961 feet, B. M., timber in platform, &c.
6,324 feet, B. M., plank in platform.
1,963.06 cubic yards masonry in walls.

To complete the lock coping is required; earth-filling against walls; the construction of slope and wing walls; application of permanent gate-hangings, &c.

The following tabular statement shows the principal items of materials and labor applied in the construction of locks above mentioned up to January 1, 1877:

Name of work.	Excavation.	Bearing-piles in foundations.		Timber.	Plank.	Masonry, including concrete in foundations.	Iron.
	Cub. yds.	*No.*	*Lin. feet.*	*Feet, (B. M.)*	*Feet, (B. M.)*	*Cub. yards.*	*Lbs.*
1 Grand River lock	9,427	513	7,778	117,520	47,646	1,870.47	8,671
2 Princeton lock	8,051	501	7,960	106,316	43,168	1,529.18	8,362
3 White River lock	12,705	513	8,940	114,674	48,069	1,863.89	8,252
4 Berlin lock	8,270	499	7,644	107,904	41,468	1,512.48	8,133.7
5 Eureka lock	11,000	410	7,380	120,997	53,800	1,654.50	25,003
6 Appleton (second) lock	9,471	......	....	17,501	3,820	3,715.00	1,584
7 Little Chute (upper combined) lock	7,109	......	....	60,644	36,686	2,526.07	4,911.4
8 Kaukauna (third) lock	5,576	......	....	16,547	7,034	1,798.58	1,239
9 Kaukauna (fourth) lock	6,051	......	....	15,961	6,324	1,963.06	1,212
Totals	77,660	2,436	39,702	678,064	288,015	18,433.23	67,368.1

10. CEDARS DAM.

But little progress was made on this work until after the middle of August, owing to the high stage of water, which made the construction of coffer-dams for closing the gap almost impracticable. Work was carried on however, as opportunity offered, and the dam was finally completed December 20, 1876, except the placing of clay and gravel backing.

There has been applied to the construction of this work the following items of labor, &c., exclusive of those in coffer-dams and other auxiliary works:

864.5 cubic yards dry-stone wall in abutments.
39.42 cubic yards masonry wall in abutments.
278,924 feet, B. M., pine timber and plank.
17,602 pounds iron, bolts, &c.
1,608 cubic yards embankment.

11. LITTLE CHUTE DAM.

As at the Cedars so here but little was accomplished until after the middle of August. Indeed the history of the Cedars is also that of the Little Chute Dam. The latter was completed, except clay and gravel backing, December 21, 1876.

Principal items of materials and labor in the work:

798 cords stone filling.
393.84 cubic yards dry stone wall in abutments.
31.63 cubic yards masonry wall in abutments.

274,889 feet, B. M., timber and plank.
16,256.32 pounds iron, bolts, &c.
2,407 cubic yards embankment.

The above does not include anything used simply in coffer-dams and other auxiliary works.

12. KAUKAUNA DAM.

Owing to high water no attempt to close the break of the preceding spring was made at this work during the summer. And subsequently on account of the limited funds available it was decided to do nothing more than was necessary to obviate further damage during the winter. Accordingly the ends of the dam adjoining the break were built up and solidly filled; protect on cribs were sunk against each of these ends projecting beyond them in such manner as to secure them against damage by ice and other floating bodies. This was done during the months of October and November.

Exclusive of materials in coffer-dams and other auxiliary work, the following are the principal items, applied to date, in the construction of this dam:

662.28 cords stone filling in dam.
63.46 cubic yards dry stone wall in abutments.
256,131 feet, B. M., timber and plank.
12,168 pounds iron bolts, &c.
3,091 cubic yards embankment.

13. RAPID CROCHE DAM.

As originally located, the south end of this dam abutted against the river-wall of the old Rapid Croche lock. At the commencement of the past year it was determined to carry the dam to the main shore cutting through the old lock. By so doing the abutment was made much more secure, and the dam lengthened something over 60 feet, a point of considerable importance, as this dam was shorter than any of the others on the Lower Fox.

The necessary coffer-dams for making this extension were built in July; some of the bottom timbers were placed and the masonry of south abutment was commenced; in the mean time the work of filling, sheathing, and coping other parts of the dam was going on. Owing to high water, but slow progress was made. By the middle of August, however, the water had fallen considerably, and operations were proceeding very satisfactorily, when, unfortunately, it became necessary to discharge the force, and suspend all work there (August 26) until a determination had been reached as to the application of the new appropriation. Work was not resumed until about the middle of September, and from then until the 1st of October, most of the time was spent in repairing damage done to coffer-dams, &c., during the temporary suspension of operations. Work was then continued until December 5, when all was closed for the winter, leaving cribs ready placed for coffer-dam of the "gap" (in length about 30 feet at bottom) between the two completed portions of dam.

The principal items of labor and materials applied to this work up to date of suspension, are as follows:

473 cords of stone filling.
106.75 cubic yards dry-stone wall in abutments.
13 cubic yards masonry stone wall in abutments.
170,328 feet, B. M., timber and plank.
9,590 pounds iron bolts, nails, &c.
2,776 cubic yards embankment.

Materials used in coffer-dams and other auxiliary work do not appear in the above statement.

14. LITTLE KAUKAUNA DAM.

Considerable damage had been done to this structure during the winter of 1875–'76, as described in my last annual report. Owing to continued high water, it was impossible to accomplish much in the way of repairs, or continuation of the work, until late in the summer, and all operations here were attended with great difficulty throughout the season; but by the 1st of December the work was practically completed and operations suspended.

During the season, besides straightening up and bracing every sound pile left in the dam, 33 broken ones were removed and replaced by new ones. The dam, as finished, contains the following, exclusive of materials used in coffer-dams and auxiliary works:

815 cords stone filling.
119 cubic yards dry-stone wall in abutments.
56 cubic yards masonry wall in abutments.

154,366 feet, B. M., timber and plank.
345 (9,158 linear feet) piles.
10,610 pounds iron, bolts, &c.
6,543 cubic yards embankment, clay and gravel backing.

The following tabular statement shows the *principal* items of labor and materials applied to the construction of the dams before mentioned, up to January 1, 1877:

Name of work.	Stone filling in dams.	Dry stone wall, (abutments.)	Masonry in abutments.	Timber and plank in dams.	Iron in dams.	Embankment.	Piles in dams.	
	Cords.	*Cu. yds.*	*Cu. yds.*	*Ft., B. M.*	*Lbs.*	*Cu. yds.*	*No.*	*Lin. ft.*
10. Cedars Dam	864.5	117	39.42	278,924	17,602	1,608	......	....
11. Little Chute Dam	798	393.84	31.63	274,889	16,256.32	2,407	......	....
12. Kaukauna Dam	662.28	63.46	....	256,131	12,168	3,091	......	....
13. Rapid Croche Dam	473	106.75	13	170,328	9,590	2,776	......	....
14. Little Kaukauna Dam	815	119	56	154,366	10,610	6,543	345	9,158
Totals	3,612.78	800.05	140.05	1,134,638	66,226.32	16,425	345	9,158

The tabular statements for locks and dams show the following grand totals, no account whatever being taken of the vast amounts of labor and material applied solely to the construction of auxiliary works, such as coffer-dams, &c.:

Total masonry, cubic yards	18,573.28
Total dry-stone wall, cubic yards	800.05
Total stone filling, cords	3,612.78
Total piles, linear feet	48,860.00
Total timber and plank, feet, B. M	2,100,717.00
Total iron, pounds	133,594.42
Total excavation, cubic yards	77,660.00
Total embankment, cubic yards	16,425.00

The above quantities refer only to the *new* works, constructed between the beginning of August, 1875, and December 31, 1876. They include no previous works, such as the stone dam at Appleton, nor the lower combined lock at Little Chute, larger than any of the others, nor is any showing made of the amounts applied to repairs on old locks, dams, canal-banks, &c.

15. EUREKA DAM, (TEMPORARY.)

In order to open navigation through Eureka lock, and obtain reliable data as to the extent of back-water arising from the construction of dams, a temporary dam of brush and stone was built, raising the water to the proposed level. This work was accomplished at small expense in September and October. Its effect verifies the correctness of our calculations; the back-water extends nearly to Berlin, and has caused a notable decrease in the current at that place, while the amount of flowage is insignificant.

16. DREDGING.

But little was accomplished in this line during the year. In July the new dredge, built toward the close of the preceding year, was put on trial, and continued to work until August 22. In connection with this dredge, the device, shown on the accompanying plates, for depositing the excavated materials on the river-banks was tried, and promises to be a very desirable auxiliary. By means of this arrangement the material is carried well back from the river with but one handling, and the cost of dredging wide channels thereby materially lessened.

The affair consists essentially of a hopper supported on a scow, which is anchored in a convenient position beside the dredge. A wrought-iron chute, made in lengths convenient for handling, connects with the hopper to conduct the material to the place of deposit. The earth is dumped directly into the hopper, and is washed out and down the chute by water supplied through openings in the back of the hopper. The pump which supplies the water is on the dredge. The entire arrangement was devised by Capt. R. S. Littlefield, of Chicago, now, and for a long time past, connected with lake-harbor improvements.

This dredge worked in all 28 days, of 10 hours each, and in this time excavated from the bar below Eureka about 9,000 cubic yards, and from the canal above Eureka lock

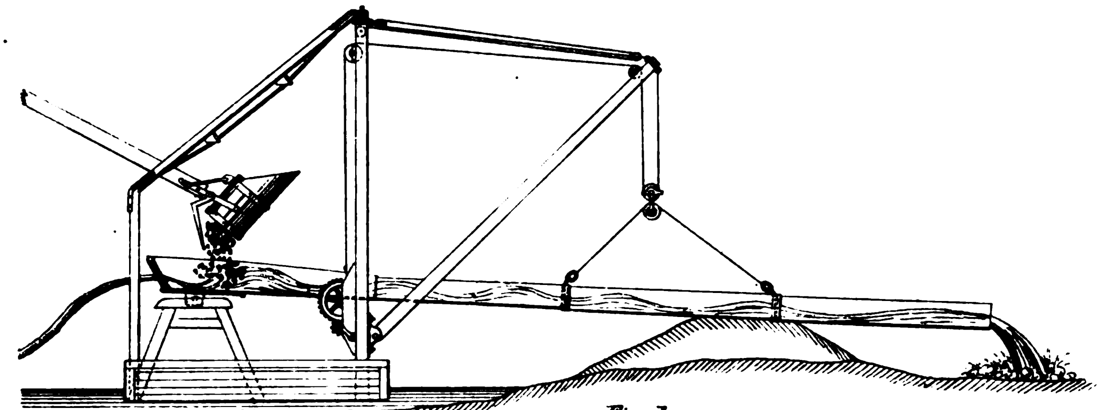


Fig. 1.

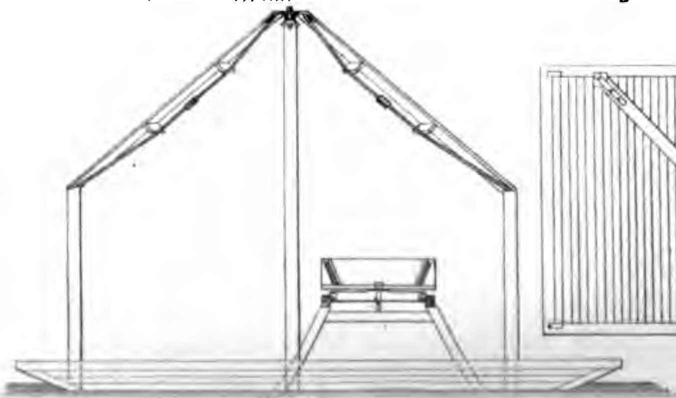


Fig. 2.

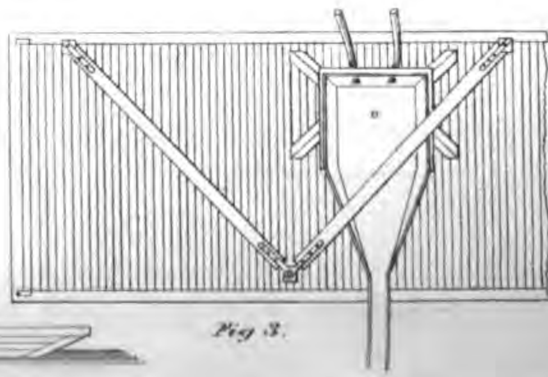


Fig. 3.

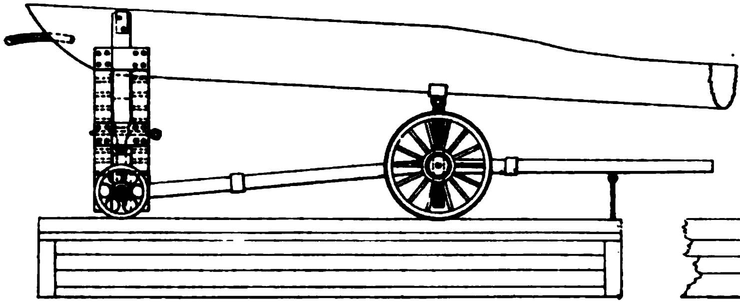


Fig. 4.

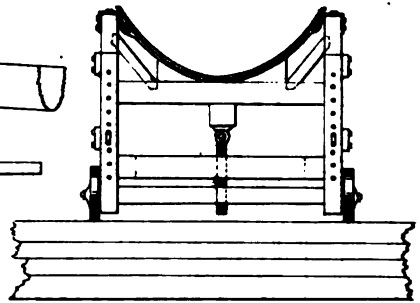


Fig. 5.

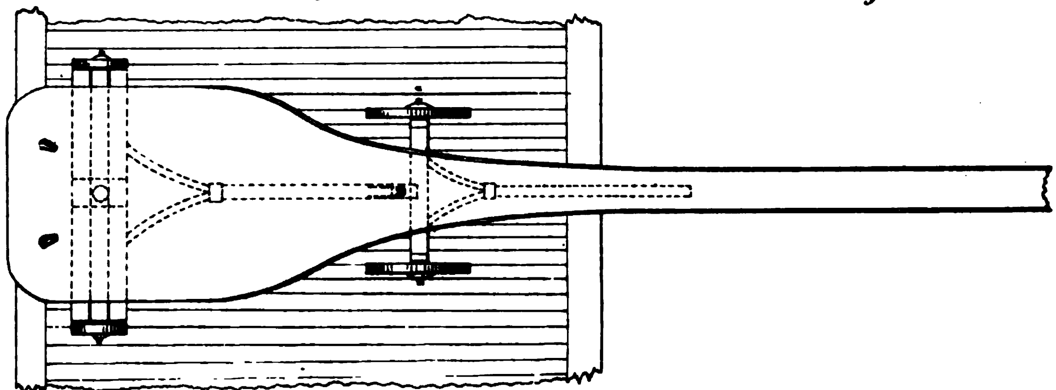


Fig. 6.

13,200 cubic yards, a total of 22,200 cubic yards, being a daily average of 800 cubic yards, nearly. As most of this work was to a great extent experimental, and with new machinery, I have no doubt that this average can be greatly exceeded.

In addition to this dredging, one of the old dredges (No. 2) worked on the cut-off at Horseshoe bend from August 8 to 25, excavating 7,000 cubic yards, and enlarging the cut enough to make it navigable.

This is a great help to navigation at this locality, but still more work is needed to complete the job.

The other dredge (No. 1) required considerable repairs, particularly of machinery. These had been commenced, but before they could be finished all dredging operations were suspended (August 25) for the season, on account of lack of funds.

17. SURVEY OF THE LOWER FOX.

A small party was sent out toward the end of August to supply certain omissions in the work of the preceding year and complete this survey. A fair start only was made, when, under instructions to limit expenditures, it became necessary to recall the party. But little was accomplished, and the subject is mentioned only to record the circumstances attending the death of Henry Liljencrantz, the assistant in charge of the work. During the short time he was in the field he contracted a severe cold, through exposure in the line of his duty. Immediately after his return to the city pneumonia set in, and his death followed very suddenly, after two days of most intense suffering. His friends and associates were hardly aware of his illness before they were called upon to mourn his loss. Of the highest ability in the duty to which he was assigned, and on which he had been engaged under my immediate directions during the past three years, his loss will be seriously felt on the work and in the office. He was always ready, zealous, active, and, above all, accurate and thoroughly reliable. In a word, he lacked none of the qualities which the most exacting would require in an efficient and trusted assistant.

In his social relations he was no less conspicuous, a fact to which the crowded state of one of Milwaukee's largest churches bore striking testimony on the occasion of his funeral.

While it is due to his memory that his worth should be acknowledged in this official manner, this report is not the proper place in which to express at greater length my own appreciation of and friendship for him.

18. MISCELLANEOUS.

After the close of operations in the field, a small force was organized to build new lock-gates for some of the old works on the Lower Fox; this work continued until the middle of March, when arrangements were made for putting them in at Depere, Rapid Croche, and Little Kaukauna locks.

In addition to new gates, the lock at Depere required quite extensive repairs, and it was necessary to build coffer-dams above and below, and pump the lock out. This was in progress at the time I was relieved. At the same time the Menasha lock was pumped out, principally to replace and secure the upper miter-sill.

Notwithstanding several breaks in the canal-banks on the Lower Fox during the past year, we have had less than the usual trouble in this line. The most serious break was in the Kaukauna river-level, opposite the site of the north abutment of the new dam.

A coffer-dam covering the limits of the break was built as a temporary remedy.

During the past winter a series of drawings, showing full details of the new locks on the Upper Fox, was prepared by John Pierpont, assistant engineer, who had been in immediate charge of their construction. The manner in which he has executed this work, as well as all to which he has been assigned while on duty as my assistant during the past three years, merits the warmest commendation. Whatever of success I may have met with in the conduct of this work has been largely due to the efficient aid received from him, both in preparing our projects and executing them.

In conclusion, I can only express the deep regret with which I am now called away from this duty.

Very respectfully, your obedient servant,

G. J. LYDECKER,
Captain of Engineers.

Maj. D. C. HOUSTON,
Corps of Engineers, U. S. A.

REPORT OF LIEUTENANT F. A. HINMAN, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 2, 1877.

SIR: In accordance with your instructions of the 27th ultimo, I have the honor to submit the following report of operations on my section of the Fox River improvement for the fiscal year ending June 30, 1877.

By your order of the 10th ultimo my charge over the said improvement was extended from Buffalo Lake to the mouth of Mechan River.

1. GUARD-LOCK, NEW GUARD-LOCK AND BASIN.

Last fall the sand in the upper approach to the guard-lock was dredged out for the second time during the season, this time by dredge No. 4; she dredged it out again last May, working there 2 days. A wide and deep cut was made across the channel a short distance above this lock for the reception of sand; estimated amount of material dr dged, 1,500 cubic yards.

Periodical dredging will be required here. No radical change is noted in the bank of the Wisconsin River just below the lock; this is attributed to the unusual low water of this season. It is the intention to protect this bank some time in the future.

The settlements in the cribs of the guard-lock were filled up with clay, the lower gates replanked, and all the gates strengthened. Boats drawing 3 feet can pass through this lock at any time by raising the water in the canal to within 6 inches of the top of the timber revetment. This is the greatest depth that can be obtained on the lower miter-sill. Borings were completed at site of new guard-lock. Nothing has been done about said lock and basin since date of last annual report, except to appraise the land.

2. PORTAGE CANAL.

A temporary revetment of brush and stone 923 linear feet in length was built along the site of the proposed basin (from the guard-lock to a point near Wisconsin-street bridge) to protect the bank. It serves the purpose well. Minor repairs were made to Wisconsin-street bridge; it is proposed to rebuild this bridge after the close of navigation, placing it squarely across the canal to Dewitt street.

At present it crosses the canal obliquely, so that the north terminus shall be at a point equally distant between Wisconsin and Dewitt streets, a compromise that damages the north approach to the bridge.

The proposed changes in it, and also the questions relating to the repairs of the sidewalk along the approach to it from the north, are now being considered.

The city of Portage has established and maintains a floating draw-bridge at Ketchum's Point, just below the Chicago, Milwaukee and Saint Paul Railroad Company's upper draw-bridge. The lower draw-bridge belonging to this company is a detriment to navigation as it now stands, as some boats have difficulty in passing through it. Water was let into the canal a year ago the 30th ultimo, and has remained in ever since, so that the canal-banks and present waste-weir have been well tested. A little settlement of the filling of the latter (which was expected when first built) was filled up with clay.

The canal timber revetment has stood well, except some of that built according to the first system, which heaved in a little before the canal was filled with water; not much change is noted since. The second system of revetment is considered better than the other.

3. WINNEBAGO LOCK.

Minor repairs were made to the gates of this lock, and settlements in cribs filled up with clay.

4. GOVERNOR'S BEND LEVEL.

The land clam-shell steam-excavator borne temporarily on two of the Wisconsin River scows worked 35¾ days on this level, during which time it is estimated that she removed 11,680 cubic yards of material. She was laid up for the season August 31, and has not been employed since. Her roof has been repaired, and it is proposed to build a suitable hull for her the coming winter, a plan of which has been prepared.

The bar that was dredged out last season just below Winnebago lock re-formed; it was 300 feet in length, and was dredged out in May by dredge No. 4; estimated amount of material removed, 2,000 cubic yards. It is presumed that dredging will be required at this point periodically, as the sand in the Fox River just above navigation is constantly coming down.

The Wisconsin Central Railroad Company did not change the location of its bridge, as proposed, but instead dredged above it on the left bank, and below it on the right bank a short distance, as requested, thereby improving the approaches; 5,000 cubic yards of material were removed for this improvement. The company is about putting in a number of piles, as desired, to still better the approaches.

5. GOVERNOR'S BEND DAM AND LOCK.

The crest of this dam was lowered 1 foot, as there was sufficient water in the level above, after the removal of the bar below Winnebago lock; this change, of course, affected the marshes above, where flowage damages are claimed.

Minor repairs were made to this lock. The lock-gates were kept open all winter, as the lock and dam are old, and too weak to withstand the sudden spring changes.

6. MONTELLO LEVEL.

Last July, soundings showed a channel in this level from 3.4 feet to 9.5 feet in depth the water standing 6.8 feet on the lower miter sill of Governor's Bend lock. The bar 600 feet in length, which had been gradually forming for some years below said lock, was removed by dredge No. 4. Estimated amount of material dredged, 3,000 cubic yards. Soundings taken last month disclosed a channel along this level from 3½ feet to 9¾ feet in depth, the water standing 4.5 feet on lower miter-sill of said lock.

After removing 67 large bowlders from the channel near Port Hope draw-bridge, dredge No. 4 proceeded to Grand River level.

7. GRAND RIVER LEVEL.

On the 16th ultimo, dredge No. 4 commenced work on the bar at the mouth of Montello Creek, (just below Montello lock.) She worked here 6 days, and removed about 1,700 cubic yards. It is believed that periodical dredging will be required at this point, as dredging was done here last year.

After removing said bar, dredge No. 4 commenced work on the construction of the upper level of Grand River Canal; she has made a cut 280 feet long, removing 2,811 cubic yards. The entire cut will be 50 feet wide, (for the present,) and 1,930 feet in length.

8. GRAND RIVER LOCK AND DAM.

It is proposed to build the slope and wing walls of this lock of tight timber cribs filled with stone and clay. All materials requisite for their construction have been delivered, and work on same is being rapidly prosecuted. The miter-sills will be placed shortly, and gates hung as soon as the iron-work for same is completed.

Preparations are now being made for the early completion of a temporary brush and stone dam at this point similar to those on the Wisconsin River, except that 2 small cribs (on hand) will be put into it.

It is thought that this lock will be ready for service early next month.

9. PRINCETON LEVEL.

On completion of Grand River Canal, dredge No. 4 will work on this level. But 1 bar of much consequence exists between Grand River lock and the mouth of Mechan River; it does not affect navigation at present, but would at low-water stage.

10. MISCELLANEOUS.

There has been a general complaint of low water throughout the Northwest this year, which has somewhat affected the above levels.

The Fox River has been fed as required from the Wisconsin River; this, with the aid of the recent rains, has materially benefited navigation.

Last month I made a tour of inspection in your company from Portage to Princeton level on the United States steamer Winneconne, drawing 27 inches. The *Winneconne* is 110 feet long, 20 feet beam, and has a 6-foot guard. A bar in Princeton level (above referred to) prevented her going farther; (the river has risen a foot since.) All completed locks were found to be in working order.

Through navigation was opened over the above section the 7th of last July. It has since been obstructed somewhat by bars and low water, but it is thought that a fair 3-foot channel now exists the entire length.

Dredge No. 4 was purchased and towed from Prairie du Chien to Portage last summer.

The amount of tolls collected on this section was small. The traffic consisted principally of lumber and grain.

Very respectfully, your obedient servant,

F. A. HINMAN,
First Lieutenant Corps of Engineers.

Maj. D. C. HOUSTON,
Corps of Engineers, U. S. A.

WISCONSIN RIVER.

REPORTS OF LIEUTENANT F. A. HINMAN, CORPS OF ENGINEERS.

1.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 2, 1877.

SIR: In accordance with your order of the 27th ultimo I have the honor to submit the following report of operations on the Wisconsin River improvement for the fiscal year ending June 30, 1877:

Owing to lack of funds no field-work has been done since November, 1875, except to take soundings, from time to time, along the upper section of the improved river. The last soundings were reported in my letter to you of the 13th ultimo, a copy of which is inclosed herewith.

There was no spring rise this year like those of former seasons; a low stage of water prevailed until the rise due to recent rains.

Six of the boats belonging to the improvement are now temporarily engaged on the Fox River improvement; the balance of the boats and property are at Portage in fair condition.

It is respectfully recommended on the score of economy that operations be not resumed on this improvement until sufficient funds are available to work on a large scale.

Very respectfully, your obedient servant,

F. A. HINMAN,
First Lieutenant Corps of Engineers.

Maj. D. C. HOUSTON,
Corps of Engineers, U. S. A.

2.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., June 13, 1877.

SIR: In accordance with your verbal orders of the 8th instant, I have the honor to submit the following list of soundings taken by me the 7th instant, under your personal observation, on the United States steamer Winneconne, (drawing 27 inches,) in the Wisconsin River, between the guard-lock at Portage, Wis., and dam No. 8, 1872, about 12 miles below Portage.

The gauge-reading at Portage on the 7th instant was six-tenths of a foot above low water of 1872, or four-tenths of a foot above low water of 1867, (low water of 1872 was two-tenths of a foot below low water of 1867.) It is proper to state that these soundings were not taken under the most favorable circumstances, as they were taken while going down stream, and the time necessarily chosen was just after a hard rain, when the wind blew quite strongly at times, thereby rendering the boat more unmanageable than she would have been otherwise, and also disturbing the surface-marks of the water, that often guide the pilot, who, by the way, had not been over this reach in some weeks, and then on a raft. "N. B." indicates no bottom (the deepest soundings, of course) with a pole 14½ feet in length. The least sounding taken was 4 feet, except one of 3 feet, and two of 3.7 feet on and about the end of an old timber-dam at Portage, a portion of which must be removed. It is thought that a settlement in a dam above is somewhat detrimental to this locality. It is worthy of note that the depth of water in the channel along this reach has improved (about 1 foot) since 1875, as was anticipated, without further work; then the least sounding taken was 3 feet, the gauge-reading at Portage being two-tenths of a foot above low water of 1872. (See page 420, Report of the Chief of Engineers, 1876, Part II.) It is believed that better soundings would have been obtained had all the dams been in good repair. A few of them require considerable work, as they could not be repaired at the proper time. Rafts have damaged some a little by "snubbing" against them.

Very respectfully, your obedient servant,

F. A. HINMAN,
First Lieutenant Corps of Engineers.

Maj. D. C. HOUSTON,
Corps of Engineers, U. S. A.

List of soundings (not reduced) commencing at guard-lock and ending at Dam No. 8, 1872.

Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.
1	4.	44	5.4	87	8.2	130	5.7	173	8.	216	N. B.	259	5.8
2	4.5	45	5.	88	6.	131	5.7	174	7.8	217	N. B.	260	5.7
3	3.	46	6.6	89	6.6	132	N. B.	175	7.7	218	N. B.	261	7.6
4	3.7	47	6.4	90	7.1	133	7.8	176	N. B.	219	N. B.	262	7.6
5	4.	48	6.	91	7.7	134	5.	177	N. B.	220	N. B.	263	7.
6	3.7	49	5.1	92	7.2	135	4.8	178	8.8	221	N. B.	264	6.7
7	5.	50	7.7	93	7.1	136	4.6	179	7.	222	N. B.	265	5.7
8	5.	51	6.1	94	6.6	137	6.	180	5.6	223	6.4	266	5.5
9	4.8	52	5.7	95	6.1	138	7.	181	5.4	224	5.3	267	8.
10	4.5	53	5.	96	5.7	139	7.7	192	5.	225	5.	268	7.9
11	8.	54	4.4	97	5.3	140	6.6	183	5.8	226	4.1	269	7.
12	6.8	55	6.4	98	6.2	141	5.8	184	10.4	227	3.8	270	6.1
13	7.	56	6.8	99	N. B.	142	5.1	185	9.	228	5.2	271	N. B.
14	5.	57	6.1	100	8.1	143	6.2	186	8.1	220	5.7	272	7.4
15	4.8	58	4.5	101	6.2	144	5.	187	6.	230	3.7	273	6.
16	4.8	59	4.	102	6.	145	5.5	188	5.7	231	5.5	274	6.2
17	7.4	60	8.	103	5.1	146	6.4	189	8.	232	4.5	275	6.
18	6.6	61	7.3	104	4.8	147	5.2	190	7.8	233	4.1	276	9.1
19	6.5	62	5.5	105	5.8	148	4.2	191	7.7	234	4.1	277	6.3
20	6.7	63	5.8	106	6.7	149	5.	192	5.4	235	4.3	278	6.
21	7.4	64	N. B.	107	7.	150	5.2	193	5.	236	4.7	279	6.
22	5.8	65	N. B.	108	6.1	151	5.7	194	5.1	237	4.1	280	6.5
23	4.2	66	8.3	109	4.8	152	5.4	195	6.3	238	4.6	281	4.2
24	4.	67	6.	110	4.4	153	5.2	196	N. B.	239	4.2	282	4.9
25	7.	68	6.4	111	N. B.	154	4.1	197	8.7	240	4.8	283	4.4
26	7.9	69	6.6	112	9.	155	4.	198	7.1	241	5.8	284	N. B.
27	7.4	70	6.	113	8.6	156	4.8	199	5.3	242	5.3	285	N. B.
28	8.	71	5.8	114	8.4	157	7.4	200	4.4	243	5.	286	6.1
29	6.1	72	5.7	115	6.	158	6.	201	5.1	244	4.8	287	6.3
30	4.9	73	4.8	116	6.	159	6.	202	6.4	245	7.1	288	7.
31	N. B.	74	7.	117	5.6	160	4.7	203	8.	246	5.	289	8.2
32	7.7	75	5.8	118	5.	161	5.	204	7.8	247	4.8	290	6.3
33	7.5	76	4.1	119	4.9	162	6.2	205	7.4	248	6.6	291	5.3
34	5.9	77	4.0	120	5.4	163	5.7	206	7.	249	5.8	292	5.8
35	5.4	78	4.6	121	5.	164	8.2	207	5.7	250	4.9	293	5.4
36	7.1	79	4.4	122	4.7	165	7.	208	5.6	251	5.1	294	4.
37	6.8	80	4.7	123	4.	166	6.4	209	6.7	252	N. B.	295	4.3
38	7.5	81	5.4	124	4.5	167	6.1	210	7.4	253	6.1	296	4.4
39	N. B.	82	N. B.	125	4.1	168	7.8	211	7.6	254	5.	297	N. B.
40	8.3	83	9.	126	4.1	169	7.4	212	6.8	255	6.9	298	N. B.
41	6.1	84	8.8	127	4.5	170	7.1	213	7.2	256	5.7	299	8.2
42	5.4	85	6.	128	5.	171	6.4	214	6.3	257	5.	300	7.
43	6.	86	5.7	129	5.7	172	7.3	215	6.1	258	6.		

APPENDIX A A.

ANNUAL REPORT OF CAPTAIN G. J. LYDECKER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Chicago, Ill., July 14, 1877.

GENERAL: I have the honor to transmit herewith annual reports of operations for the fiscal year ending June 30, 1877, relating to the improvements of harbors now in my charge.

Very respectfully, your obedient servant,

G. J. LYDECKER,
Captain of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

A A 1.

IMPROVEMENT OF THE HARBOR AT CHICAGO, ILLINOIS.

I assumed charge of this work early in May, relieving Maj. G. L. Gillespie, per Special Orders No. 85, Adjutant-General's Office, Washington, D. C., April 21, 1877.

At the beginning of the year, Mr. W. L. Smith, contractor, was engaged in building the superstructure of the north pier-extension, four courses having been completed. The length of the extension was 600 feet. In continuation of this work, during the months of July and August, the remaining three courses were finished, stone filled to the top, and the entire superstructure planked. Snubbing-posts were placed at intervals of 100 feet. A clump pile-protection, similar to that used at the north end of the breakwater, was commenced at the end of the pier, but a lack of funds compelled the suspension of this part of the work after driving and capping 24 piles. In the mean time the close pile-protection for the breakwater had been extended toward the south a distance of 292 feet. The total length of protection for the breakwater is now 1,300 feet.

Nothing further was done on the improvement at this place until the month of June, when the compartments of breakwater-cribs were refilled as far as necessary to provide against settlement of stone, which had taken place since the completion of the work in 1875.

The breakwater and all portions of the piers built since 1869 are now in good condition. On work done prior to that date, however, considerable repairs are needed. This is particularly the case at the old lighthouse pier where the superstructure is rotten, broken, and in some cases so opened as to allow the stone filling to pass through and fall in the channel.

The amount appropriated for this work by the act approved August 14, 1876, was $5,000; of this amount only $1,000 was allotted and available for expenditure until May 1, 1877; at this date the expenditure of the balance ($4,000) was authorized. It has been applied in part to refilling cribs of breakwater; the remainder will be applied to extending the pile-protection of the north pier-extension, after making such repairs on the old work as are needed at once. All to be done by open purchase and hired labor, as authorized by Department letter of May 9, 1877.

The question of modifying the project for the outer harbor as fixed by the Board of Engineers in 1870 is still to be decided, but until it is brought before another board it is probably only necessary to add to the remarks of my predecessors on this work, that, whether protection from southerly storms be sought by a line of breakwater at right angles to that now finished in extension of it, or in any intermediate direction, a suitable opening should be left to enable vessels missing the harbor-entrance between the piers to gain shelter by rounding the southerly end of the present breakwater. In northerly storms almost all vessels whose draught will warrant it now enter the harbor in this way rather than by rounding the north pier and running the risk of bringing up on the breakwater. To enable *all* vessels to do so, considerable dredging is required in the outer basin. For this purpose an appropriation of $40,000 is recommended.

In order that full advantage of the work done may be realized, I would earnestly recommend the appropriation of $100,000 for continuation of breakwater construction. The present works give shelter against northerly and easterly storms, but the roadstead is open to storms from the southeast and south.

For necessary repairs on existing works an appropriation of $10,000 is required.

Chicago harbor is in the collection-district of Chicago. There is a light-house on the shore-end of the north pier, a beacon-light on the lake-end of the same, and one at the south end of the breakwater.

The number of vessels entered during the year, 9,038; cleared, 9,045.

Total tonnage of vessels entered and cleared, 5,869,064. Amount of revenue collected during the year, $1,406,529.05.

The original estimated cost of the work as now being carried on was $897,095.73.

The whole amount appropriated since its adoption is $538,000, of which amount $535,330.52 had been expended to June 30, 1877.

Money statement.

July 1, 1876, amount available	$15,524 92
Amount appropriated by act approved August 14, 1876	5,000 00
	20,524 92
July 1, 1877, amount expended during fiscal year	17,855 44
July 1, 1877, amount available	2,669 48
Amount (estimated) required for completion of existing project	300,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	150,000 00

AA 2.

IMPROVEMENT OF THE HARBOR AT CALUMET, ILLINOIS.

I was assigned to this work by Special Orders No. 85, Adjutant General's Office, dated Washington, D. C., April 21, 1877, and assumed charge early in May, relieving Maj. G. L. Gillespie, Corps of Engineers.

At the beginning of the year there was no work in progress, the amount of money available July 1, 1876, not being sufficient to do anything toward the extension of the improvement. The act approved August 14, 1876, appropriated $20,000, but of this only $1,000 was made available until April 21, 1877, when the expenditure of the balance ($19,000) was authorized. It had been the original intention to apply this appropriation to extending the south pier 250 feet, and to dredging about 20,000 cubic yards between the piers. On account of the rapid accumulation of sand north of the north pier, the water had so shoaled at the harbor-entrance by sand working around the end of the pier that a bar, with a channel of only 11 feet over it, had formed there. It became necessary, therefore, to apply the money toward extending the north instead of the south pier, and to dredge this outer bar as well as through the shoal between the piers. This project was approved, and its execution, by hired labor and open purchase, was authorized by Department letters of April 21 and 27.

Dredging was commenced May 1, and continued to the end of the year, up to which time 13,886 cubic yards had been excavated. In the mean time, materials for the north pier-extension have been purchased, and the work of framing cribs was commenced during the latter part of June. It is proposed to suspend dredging operations after completing one more cut across the outer bar, which will give a good channel 100 feet wide. It can then be finished with more permanent benefit after the pier has been extended. It is expected to have the pier-work completed by the end of August.

Except about 300 feet on the lake side of the south pier, all the pier-work at this harbor is in good order, and requires but very slight repairs. On the excepted part, the pier-filling has been undermined and washed out, but the repairs may be made at slight cost. The shore-line is gradually receding south of the south pier, the total amount at its junction with the pier being about 200 feet since the work was started. The distance across the sand-spit which separates the lake from the old outlet of the Calumet River has been thereby reduced to such an extent that I propose putting a slight shore protection for a short distance, say 50 or 100 feet, south of the pier, to prevent the sea cutting through into the river.

Since the beginning of the work, in 1870, the shore-line north of the piers, at its junction with the north pier, has advanced about 800 feet, being an average annual advance of 115 feet. This amount was exceeded last year, the shore having made out 212 feet from April, 1876, to July, 1877. There has been a corresponding movement of the deep-water lines.

The 12-foot curve is now 200 feet beyond the end of the north pier, and hence the bar before spoken of at the harbor entrance had formed, with 8 feet of water, at a point about 300 feet from the end of the north pier. The 16-foot curve is 400 feet in advance of the north pier, while the distance to the 18-foot curve is 750 feet. In my opinion, the pier will have to be extended to this limit within the next two seasons, in order to keep the entrance clear; and the extension to the 16-foot curve should be made next season, in order to save in dredging. This will require 250 feet of pier-work in addition to that now being built. The extension of the south pier 250 feet, as recommended by Major Gillespie, in his report for 1875, should be done at the same time. For this pier-work at least $40,000 will be required, and for dredging there will be needed $10,000 more. I have therefore to recommend an appropriation

of $50,000 for the continuation of this work during the fiscal year ending June 30, 1879.

A survey, showing the limits of the bar and the other changes at this harbor, was in progress at the close of the fiscal year.

Calumet Harbor is at South Chicago, a port of entry in the collection-district of Chicago.

There is a light-house on the lake-end of the north pier.

The number of vessels entered during the year, 72; cleared, 72; total tonnage of vessels, 22,514; amount of revenue collected during the year, $72.50.

The original estimate for this improvement was $299,875.52. There has been appropriated to date $250,000, leaving in round numbers a balance of $50,000 to complete the work with. The amount expended up to July 1, 1877, was $237,148.76.

Money statement.

July 1, 1876, amount available	$1,807 33	
Amount appropriated by act approved August 14, 1876	20,000 00	
		$21,807 33
July 1, 1877, amount expended during fiscal year	6,648 29	
July 1, 1877, outstanding liabilities	2,307 80	
		8,956 09
July 1, 1877, amount available		12,851 24
Amount (estimated) required for completion of existing project		50,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		50,000 00

AA 3.

IMPROVEMENT OF THE HARBOR AT MICHIGAN CITY, INDIANA.

I was assigned to this work by Special Orders No. 85, Adjutant General's Office, dated Washington, D. C., April 21, 1877, and assumed charge early in May, relieving Maj. G. L. Gillespie, Corps of Engineers.

At the beginning of the year operations were suspended, while awaiting the passage of an appropriation bill. The act approved August 14, 1876, appropriated $35,000, but none of it became available until September 14, when $16,000 of the whole amount was allotted, and it was the 1st of October before active operations were fairly resumed, authority having been granted to carry on the work by open purchase and hired labor.

At the time work was stopped 12 cribs of the breakwater had been sunk, but none of the superstructure had been placed. During the suspension these cribs had settled considerably out of line and level, and when work was resumed the top courses were from 1 to 3 feet below the water-surface, while a great deal of the stone filling had been washed out. To build up these cribs and correct their alignment at that season of the year proved a most arduous task and an expensive one, but by seizing every possible chance a skilled body of workmen, under the supervision of an energetic and experienced foreman, pushed the work ahead until the latter part of November, when the first course of superstructure was finished over the entire length of the breakwater, except crib No. 1, which had separated at 8 feet below the water-surface; the second course was placed for a distance of 200 feet from the east end, and all was solidly filled with stone. The following extract from Major Gillespie's report of operations for the month of November, 1876, gives some idea of the difficulties encountered in carrying on this work:

By storm of the 3d and 4th instant, 68 linear feet of timber were broken off and came ashore, and some of the longitudinal timbers displaced. Storm of 7th and 8th

agle pieces to carry superstructure in line were torn off of crib No. 5; 14th and 15th, gale lifted two courses of timber on crib No. 5 and first course of superstructure, breaking the timber, and rendering it necessary to tear off 628 linear feet pine and hemlock timber. Storm of 22d and 23d, the angle pieces and 100 linear feet of timber again torn off crib No. 5.

The loss resulting from these storms is far greater than simply the worth of the materials broken and wasted, as working on a level with the surface of the water and below it the progress is necessarily slow and difficult—bolts broken and twisted, to be driven down or cut off; stone to be removed, that timber may fit down closely; and then the liability of a suspension of all operations by a change in the direction of the wind, causing roughness on the lake.

The disaster which put an end to all work for the winter-season is described in the following extract from the report of J. A. Manning, foreman in immediate charge of the work:

On November 28, 29, and 30 a severe gale from the northeast raged, and on December 1 it increased so that a vessel could not have made the harbor without wrecking. During the day it was noticed that No. 8 crib was lifting from its foundation, and at 5 p. m. it floated in on the beach, where it now lies, in good condition. During this blow a large quantity of the superstructure was torn off and came in on the beach.

The bulkhead at the end of old east pier was also torn out, and the superstructure of the crib badly broken. From this time forward the ice continued to make, and the stone and timber on hand for the work became covered with it, so that it was impracticable to attempt any further work outside. The force was employed in getting such timber, &c., as was worth saving from the wreck, together, and on December 9 we stopped work. During the winter considerable damage was done to the cribs. Such portions of the superstructure as survived the gale of the 1st of December were torn off by later ones, and in February, during a severe blow, No. 9 crib, which had been somewhat damaged at the time No. 8 came out, also lifted and came in on the beach.

Operations were not resumed until the end of April, when a careful examination of the work showed the damage to be even greater than had been expected. From that time until the end of June all work done has been confined to restoring the breakwater to the condition in which it was at the end of November. The cost of labor and material applied in making these repairs alone was $11,706.70, as shown by the following statement prepared by my assistant, R. S. Littlefield:

6,140	feet, board measure, pine timber, at 14 cents	$939 96
130	linear feet 12 inches by 18 inches hemlock, at 18 cents	23 40
8,703	linear feet 12 inches by 12 inches hemlock, at 14 cents	1,218 42
6,684	feet, board measure, pine plank, at 14 cents	93 57
91	cords stone, at $7.50	682 50
11,439	pounds drift-bolts, at 02.3 cents	378 14
218	pounds screw-bolts, at 5 cents	10 90
1,800	pounds spikes, at 03.2 cents	57 60
149¾	hours' work of dredge, (dredging 420 cords stone from gap, which has been used to refill work,) at $5 per hour	748 75
37¾	days' hire of diving-apparatus, at $15	566 25
	Crib bought of Culbert & Hopkins	1,735 41
263	cords stone to fill two cribs, to be sunk	1,972 50
	Towing dredge and scows to and from work	206 00
	Pay-rolls for labor, April 25 to June 30, 1877	3,072 30
	Total	11,706 70

It is proper to state in this connection that the appropriation was not made available until late in the season, authority to commence work not being granted until September 14. This, with a month's delay for procuring materials, and the severe storms incident to the locality of Michigan City at the time of year, rendered it impossible to level the cribs to the surface of the water and build enough superstructure upon them to strengthen the work against the extraordinary blow during which the damage was done.

The balance of the appropriation will be only sufficient to complete the superstructure to the fourth course, inclusive, and this will probably be accomplished by the first of August. With reference to the superstructure of this work, Captain Littlefield states:

On account of the exposure of this work, both from its position and the directio

given to the pier, to the heaviest seas made on Lake Michigan, the superstructure on its completion should be eight courses high, corresponding to works at Chicago and other harbors on the lake, where six courses are of sufficient height.

I fully agree with him on this point.

To finish the improvement at this place under the present project requires the construction of 700 feet of breakwater and the completion of the superstructure on that part already built. To do this will require $75,000, and the appropriation of the entire amount for the fiscal year ending June 30, 1879, is urged. Nothing could place in stronger light than this report the absolute necessity of making the appropriation sufficient to complete the work at once. Situated at the foot of Lake Michigan, this harbor is a most important one as a harbor of refuge, independently of the amount of commerce carried on, and the improvement should be completed at the earliest date practicable. It will be much more economical to complete it in one season than to drag it along with small appropriations for several years to come.

The work of dredging the outer harbor should be commenced next season. The estimated cost of this part of the project on beginning the work was $64,175. Of this amount I would recommend that $20,000 be appropriated for the fiscal year ending June 30, 1879. There has been considerable settlement of stone in the outer-harbor piers; so much so as to endanger their safety during the heavy storms which visit this locality. To provide against danger of damage in this way, an appropriation of $5,000 is recommended. This brings the whole amount of appropriation recommended for this work for the fiscal year ending June 30, 1879, up to $100,000. It is all needed for the proper and economical prosecution of the work.

The original estimate for completing the improvement at this place was $324,421.40. Of this amount there has been appropriated to date $235,000; the amount expended to June 30, 1877, was $226,009.89. To complete the work I estimate will require $120.000, which will make the total cost $355,000, against $325,000, the amount of the original estimate, in round numbers.

This increase of $30,000 is due to the unusual difficulties which have been experienced on these works from the very start, and the amount expended in repairs of damage to works in course of construction.

The harbor is in the collection-district of Michigan City, Ind. There is a light-house on the shore near the shore-end of the east pier, and a beacon-light on the lake-end of the west pier.

The commercial statistics of the port for the fiscal year are as follows:

Number of entrances	428
Number of clearances	421
Amount of revenue collected	$398 50

There is a great deal of lumber brought to this port for transhipment to the interior by rail. The amount received during the past year was 65,000,000 feet, board-measure.

Money statement.

July 1, 1876, amount available	$1,191 05	
Amount appropriated by act approved August 14, 1876	35,000 00	
		$36,191 05
July 1, 1877, amount expended during fiscal year	25,579 12	
July 1, 1877, outstanding liabilities	1,621 82	
		27,200 94
July 1, 1877, amount available		8,990 11
Amount (estimated) required for completion of existing project		120,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		100,000 00

AA 4.

IMPROVEMENT OF THE HARBOR AT NEW BUFFALO, MICHIGAN.

I assumed charge of this harbor early in May, relieving Maj. G. L. Gillespie, per Special Orders No. 85, Adjutant-General's Office, Washington, D. C., April 21, 1877.

No work has been done during the year, none is contemplated for the ensuing year, and no further appropriation is recommended.

The Board of Engineers, in session June 24, 1868, estimated the cost of improving this harbor at $500,000, with a subsequent annual expenditure of $10,000 for its preservation, and accordingly recommended that "the attempt to improve the harbor should be abandoned." It is of no evident necessity as a harbor of refuge; it is evidently a work of no present national importance, nor is there any local commerce even.

The amount appropriated to date is $70,000, of which $64,986.56 has been expended. No money has been appropriated since 1872.

The present condition of the harbor is as follows: the west pier is in a dilapidated state, with no filling visible; the outer end of this pier has been carried away to the shore-line. The piles of the east pier are still standing, generally in good condition, but there is no filling to be seen in place. A bar closes the entrance to the harbor between the piers, the sea in a light northerly wind breaking entirely across it during my inspection made a few days since.

New Buffalo is in the collection-district of Grand Haven, Mich. For the fiscal year there were no imports, no exports, no revenue collected.

There is no light-house at the harbor, the nearest being that at Michigan City, distant 10 miles, in a southwesterly direction.

Money statement.

July 1, 1876, amount available	$5,541 85
July 1, 1877, amount expended during fiscal year	528 41
July 1, 1877, amount available	5,013 44

APPENDIX B B.

ANNUAL REPORT OF MAJOR S. M. MANSFIELD, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Detroit, Mich., July 13, 1877.

GENERAL: I have the honor to forward herewith my annual reports relating to the works of harbor improvement under my charge for the fiscal year ending June 30, 1877.

Very respectfully, your obedient servant,

S. M. MANSFIELD,
Major of Engineers and Bvt. Lieut. Col., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

BB I.

IMPROVEMENT OF CHARLEVOIX HARBOR, MICHIGAN.

By act of Congress approved August 14, 1876, a first appropriation was made for the improvement of this harbor of $10,000. By letter of the Chief of Engineers, dated May 1, 1877, I was informed that the honorable Secretary of War had authorized the expenditure of this appropriation, and was directed accordingly to submit a project for its application. The project was in accordance with plans and estimates heretofore advanced, and consisted of dredging some 12,000 yards of sand and the construction and placing of three cribs (without superstructure) to serve as a pier-protection to the dredged channel.

A contract was entered into with Carkin & Stickney the 20th day of June for the execution of this work between the 1st of July and the 1st of November, 1877, at figures much below our estimate, which will admit of more work being accomplished than was anticipated.

In further continuance of the work of improvement here $30,000 could be very profitably expended during the fiscal year ending June 30, 1879.

Considerable trade is being developed at this point, as shown by the statement below, which will be largely extended when the work of improvement has advanced sufficiently to afford shelter to shipping and access to the little lakes.

The original estimate for this work (modified from that of August 26, 1873) amounted to $186,000. The total amount appropriated since the adoption of the present project is $10,000.

The work is located in the Michigan collection-district, Michigan. It is situated at the mouth of Pine River, which empties itself into Lake Michigan between Little and Grand Traverse Bays. The nearest port of entry is Grand Haven, Mich. The nearest light-station is at Grand Traverse.

Statement of vessels entered and cleared during the year ending June 30, 1877:

Entered: Number, 261; tonnage, 29,551; men, 1,576.
Cleared: Number, 251; tonnage 29,517; men, 1,558.

Money statement.

Amount appropriated by act approved August 14, 1876		$10,000 00
July 1, 1877, amount expended during fiscal year	$135 57	
July 1, 1877, outstanding liabilities	4,620 19	
		4,755 76
July 1, 1877, amount available		5,244 24
Amount (estimated) required for completion of existing project		176,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.		30,000 00

Abstract of proposals received and opened June 4, 1877, for improving the harbor at Charlevoix, Michigan.

	Bidders' names and residences.	Timber.		Iron.		Filling.		Dredging sand, per cubic yard.	Aggregate.
		Hemlock, per cubic foot.	Oak, per cubic foot.	Drift-bolts and spikes, per pound.	Screw-bolts and washers, per pound.	Stone, per cord.	Brush, per cord.		
1	Robert M. Steel, Saint John's, Mich	$0 21	$0 25	$0 03¼	$0 05	$9 00	$3 00	$0 25	$5,506 02
2	Carkin & Stickney, East Saginaw, Mich	24	28	05	08	6 50	4 00	18	4,620 19
3	Albert Conro, Milwaukee, Wis	24	30	03	06	5 00	4 00	24	5,032 13
4	Charles S. Barker, Sault Ste. Marie, Mich	23	28	04	05	8 00	1 75	30	6,105 88
5	Duncan Dewar, Ludington, Mich	22	30	03¼	04¾	8 25	2 00	22	5,096 95
6	Chicago Dredging and Dock Company, Chicago, Ill.	23	30	05	06	8 50	4 00	23	5,412 15
7	O. B. Greene, Chicago, Ill	25	48	05	07	8 00	3 00	25	5,695 43

Contract awarded to Carkin & Stickney, lowest bidders.

BB 2.

IMPROVEMENT OF FRANKFORT HARBOR, MICHIGAN.

For want of sufficient funds no new work was attempted during the fiscal year 1876–'77. Some necessary repairs were made, as a filling of slabs and edgings behind the south pier where the current from the little lake was cutting out the sand. The material was furnished without cost by the mill-owners.

Soundings taken May 14, 1877, show an available water-way of 11 feet between the piers; outside, and nearly on a line with the north pier, only about 10 feet of water is found for a distance of 100 feet.

The present season, under the appropriation of August 14, 1876, of $3,000, together with the balance of a former appropriation, the following work of improvement will be executed:

A contract was entered into with Robert M. Steel for a crib, 50 feet by 30 feet, to be placed in extension of the south pier; to be commenced July 1, and to be completed December 1, 1877.

The south pier east of the pier-light will receive one or two courses of timber and stone-ballast for a distance of 300 feet, to bring it to the necessary height above water and to a level with the other portions of the pier. At several places in both piers and revetments broken ties

and side timbers will be replaced by new ones. The outer crib of the south pier will have to be almost entirely refilled with stone.

Frankfort Harbor is at a prominent point on the east shore of Lake Michigan, very near the course of the deep-draught vessels plying the lakes. It is important as a harbor of refuge, and should have a permanent channel of at least 14 feet.

To carry out the recommendations made yearly since 1872 will require $22,000, and this amount could be profitably expended during the year ending June 30, 1879.

The original estimated cost of the work, (1872,) as now being carried on, was $46,000. The total amount appropriated since the adoption of the present project is $43,000. (See Report Chief of Engineers for 1875, page 244.)

The work is located in the Michigan collection-district, Michigan. The nearest port of entry is Grand Haven, Mich. The nearest light-house is at Point Betsey, (Point aux Bees Scies.) A light is shown near head of south pier.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 241; tonnage, 76,524; men, 2,769.
Cleared: Number, 237; tonnage, 76,404; men, 2,762.

Money statement.

July 1, 1876, amount available	$4,402 42	
Amount appropriated by act approved August 14, 1876	3,000 00	
		$7,402 42
July 1, 1877, amount expended during fiscal year	1,141 96	
July 1, 1877, outstanding liabilities	2,810 15	
		3,952 11
July 1, 1877, amount available		3,450 31
Amount (estimated) required for completion of existing project		22,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.		22,000 00

Abstract of proposals received and opened June 4, 1877, for improving the harbor of Frankfort, Michigan.

	Bidders' names and residences.	Timber.		Iron.		Filling.		Aggregate.
		Pine, per cubic foot.	Oak, per cubic foot.	Drift-bolts, per pound.	Screw-bolts, per pound.	Stone, per cord.	Brush, per cord.	
1	G. M. Wing, Manistee, Mich	$0 29	$0 45	$0 03½	$0 03¾	$9 00	$4 00	$3,118 88
2	Chicago Dredging and Dock Company, Chicago, Ill.	25	30	05	06	9 50	4 00	3,167 40
3	Duncan Dewar, Ludington, Mich	23	30	03¼	04¾	9 00	2 00	2,822 34
4	Robert M. Steel, Saint John's, Mich	22	25	03½	04½	9 00	3 00	2,810 15
5	James Corlett, Ludington, Mich	24	28	04½	05	9 50	3 00	3,065 99
6	Horace Butters, Ludington, Mich	25	27	04¼	05	10 75	2 00	3,286 95
7	Allen & King, Frankfort, Mich	25	25	05	07	10 00	3 00	3,243 40

Contract awarded to Robert M. Steel, lowest bidder.

B B 3.

IMPROVEMENT OF MANISTEE HARBOR, MICHIGAN.

During the fiscal year 1876–'77, with the balance of the appropriation of 1875, work was done as follows:

The south pier received an additional course of timber for a length of 450 feet, to bring it to the proper height above water, and to a level with other portions of the pier. Near the inner end of the north side revetment the filling had settled so as to endanger a loss of the stone-ballast. This stone was, therefore, removed and placed as ballast and riprap to the north pier-head, where it was much needed.

An obstruction to navigation, caused by the encroachment of the point of sand in the bend of the river, was successfully removed by the employment of a tug to dredge it with her wheel. About 75 feet was removed very quickly to a depth of 9 feet. The current has kept the channel tolerably free since, so that it has not been necessary to renew the operation.

Soundings taken on the 3d of May show an available channel-way of about 10 feet between the Government piers.

Of the new crib-work finished last year, the outer crib in the north pier has settled badly at the northwest corner, and requires releveling and ballasting and riprapping; the cribs inside of this are in good condition. The three cribs in the south pier have undergone no change in position since completion; the outer three pockets of end crib require refilling.

Under the appropriation of August 14, 1876, ($14,000,) a contract has been entered into with Squier & White to dredge away the point of sand in the bend of the river and face the bank with 320 feet of pile revetment, and to dredge the channel to a depth of 12 feet. All to be completed by November 1, 1877. The balance of funds will enable us to make the necessary repairs mentioned above.

As the further extension of the piers at this harbor is demanded, and according to the estimates a balance of $76,771 is required for the purpose, the sum of $30,000 could be very profitably expended during the year ending June 30, 1879.

For the work as now being carried on, it was estimated, (1873:)

For pier-extension	$112,000 00
And for revetment and dredging in channel, (1875)	13,771 00
Making a total of	125,771 00

The total amount appropriated since 1873 is $49,000.

The work is located in the Michigan collection-district, Michigan. The nearest port of entry is Grand Haven, Mich. The nearest light-house is the Manistee light, (discontinued on October 15, 1875.) A light is shown near head of south pier.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 1,236; tonnage, 279,850; men, 11,019.
Cleared: Number, 1,237; tonnage, 279,909; men, 11,023.

Money statement.

July 1, 1876, amount available	$10,381 78	
Amount appropriated by act approved August 14, 1876	14,000 00	
		$24,381 78
July 1, 1877, amount expended during fiscal year	10,564 42	
July 1, 1877, outstanding liabilities	6,647 57	
		17,211 99
July 1, 1877, amount available		7,'69 79
Amount (estimated) required for completion of existing project		76,771 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.		30,000 00

Abstract of proposals received and opened June 4, 1874, for improving the harbor of Manistee, Michigan.

	Bidders' names and residences.	Timber. Pine, per cubic foot.	Timber. Oak, 10 by 12 inches, per linear foot.	Timber. Oak, 4 by 8 inches, per linear foot.	Piles. White oak, per linear foot.	Piles. Northern pine, per linear foot.	Iron. Drift-bolts, per pound.	Iron. Screw-bolts, per pound.	Filling. Stone, per cord.	Filling. Edgings, per cord.	Driving piles, per linear foot.	Dredging sand, per cubic yard.	Removing slabs, per cubic yard.	Aggregate.
1	Culbert & Hopkins, Muskegon, Mich	$0 22	$0 30	$0 18	$0 13	$0 09	$0 03	$0 04	$7 50	$1 50	$0 15	$0 18	....	....
2	Squier & White, Grand Haven, Mich	20	35	20	11	06	02½	04½	8 00	1 20	14	14	$0 14	$6,647 57
3	Albert Conro, Milwaukee, Wis	22	32	08		09	03	06	8 00	2 50	18	18	16	8,104 18
4	O. B. Greene, Chicago, Ill	22	35	11	17	09	05	07	9 50	1 50	25	23	20	10,253 60
5	Charles S. Barker, Sault Ste. Marie, Mich	27	30	15	20	15	04½	05	8 00	1 50	05	25	30	10,021 09
6	Robert M. Steel, Saint John's, Mich	30	30	11	14	11	05	05½	8 50	2 00	20	22	50	10,170 02
7	Chicago Dredging and Dock Company, Chicago, Ill	23	25	08	14	10	05	06	8 50	2 00	15	18	50	8,303 08

Contract awarded to Squier & White, lowest bidders.

B B 4.

IMPROVEMENT OF LUDINGTON HARBOR, MICHIGAN.

But little was accomplished during the year with the balance left unexpended of the appropriation of 1875.

The inner end of the south pile revetment, which had lost a portion of its filling by the freezing of the filling at the water-level and the action of the current underneath, was refilled early in the spring, and a repetition of the occurrence guarded against by a sheathing of plank.

Late last fall (November 24) a report was received that the end crib of the south pier upon which the light stands, had lost a great portion of its filling; whereupon a cargo of stone was ordered to be shipped to Ludington from Chicago. Owing to the lateness of the season delay occurred in the shipment, and the severe gale of December 8 forced the crib from its place in the pier and carried it upon the beach 400 feet south of the harbor, where it now lies. The cargo of stone reached Ludington December 14. The crib stands upright in 7 feet of water and is embedded in the sand to a depth of 8 to 10 feet, and so far as can be ascertained has sustained no material damage, and can be recovered and used in the north pier to advantage.

The condition of the harbor is good. The channel, which was dredged in 1876 through the middle to a depth of about 13 feet when the level of the lake was about 15 inches higher than now, has an available waterway of about 12 feet.

The northwest corner of the outer crib, north pier, has settled badly, and needs releveling and additional stone filling. The superstructure has received some little injury from the collision of a steamer, and needs repair. The second crib from the end on south pier needs more stone filling.

Under the appropriation of August 14, 1876, ($10,000) a contract has been entered into with Duncan Dewar to place two cribs in extension of the south pier and complete superstructure over them by November 1, 1877.

It is intended to apply a portion of the funds remaining after completion of the contract to repairing the work at the places above mentioned; and, if the then remaining balance will be sufficient, to raise and place the displaced crib in extension of the north pier.

The recommendations for pier extension, as well as the estimates of 1875, are here renewed. The unappropriated balance of $26,000 can be profitably expended during the year ending June 30, 1879.

The original estimated cost of the improvements at this point was $270,682.16, but modifications from time to time in the recommendations and estimates have reduced these figures. The total amount appropriated since 1867 is $176,500.

This work is situated in the Michigan collection-district, Michigan. The nearest port of entry is Grand Haven, Mich. The nearest light-house is at Grande Point au Sable. A light is shown near head of south pier.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 646; tonnage, 120,446; men, 3,866.
Cleared: Number, 642; tonnage, 119,980; men, 3,840.

Money statement.

July 1, 1876, amount available	$2,037 03	
Amount appropriated by act approved August 14, 1876	10,000 00	
		$12,037 03
July 1, 1877, amount expended during fiscal year	1,826 47	
July 1, 1877, outstanding liabilities	6,167 53	
		7,994 00
July 1, 1877 amount available		4,043 03
Amount (estimated) required for completion of existing project		26,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		26,000 00

Abstract of proposals received and opened June 4, 1877, for improving the harbor of Ludington, Michigan.

Bidders' names and residences.	Timber. Pine, per cubic foot.	Timber. Oak, per cubic foot.	Iron. Drift-bolts, per pound.	Iron. Screw-bolts, per pound.	Filling. Stone, per cord.	Filling. Brush, per cord.	Aggregate.
Robert M. Steel, Saint John's, Mich	$0 20	$0 25	$0 3¼	$0 4¼	$8 50	$2 00	$6,201 04
James Corlett, Ludington, Mich	21½	24	4½	5	8 75	3 00	6,627 85
Horace Butters, Ludington, Mich	22	22	3½	4½	10 25	2 00	7,186 53
Gilbert & Hopkins, Muskegon, Mich	24	28	3¼	4¼	8 00	3 00	6,363 95
John E. Thomes, Chicago, Ill	23½	28	3½	4½	9 25	5 00	7,113 51
Duncan Dewar, Ludington, Mich	20	30	3	4½	8 50	2 00	6,167 53
Knapp & Gillen, Racine, Wis	22	35	4	5	8 50	4 50	6,629 37
Chicago Dredging and Dock Company, Chicago, Ill	23½	30	5	6	8 50	4 00	6,963 90

Contract awarded to Duncan Dewar, lowest bidder.

B B 5.

IMPROVEMENT OF PENTWATER HARBOR, MICHIGAN.

During the year the United States dredging apparatus removed 7,230 cubic yards of sand from the shoal portions of the channel, and the piers alongside, through which the sand found its way, were overhauled and reballasted. The outer pockets of the north pier-head were refilled, and the superstructure and fenders were repaired where found necessary.

The piers this spring were found in tolerably good condition, with the exception of the north pier head crib, which had again lost its stone-filling from the four outer pockets.

Under the appropriation of August 14, 1876, ($10,000,) a contract has been entered into with Squier & White for carrying the north side revetment eastward 500 feet, (more or less,) which will involve the removal of 5,500 yards of old slab-work and 6,500 yards of sand. The work is to be completed by the 1st of November, 1877.

The balance of funds that will remain, after completion of this contract, will be sufficient to reballast the pier-head, and to make some other repairs that are needed.

The recommendations and estimates made annually since 1873 are renewed, and the unappropriated balance of $39,200 can be profitably expended during the next fiscal year.

Original plan of improvement (1866) required a sum of $327,713.40. Estimates rendered since then require a less amount of money for expenditure. There has been appropriated to this harbor $153,000 from 1867 to 1876, inclusive.

This work is situated in the Michigan collection-district, Michigan. The nearest port of entry is Grand Haven, Mich. The nearest light-house is at Petite Pointe au Sable. A light is shown near head of south pier.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 260; tonnage, 23,916; men, 1,288.
Cleared: Number, 258; tonnage, 23,619; men, 1,250.

Money statement.

July 1, 1876, amount available	$1,703 63	
Amount appropriated by act approved August 14, 1876	10,000 00	
		$11,703 63
July 1, 1877, amount expended during fiscal year	1,874 47	
July 1, 1877, outstanding liabilities	5,957 86	
		7,832 33
July 1, 1877, amount available		3,871 30
Amount (estimated) required for completion of existing project		39,200 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		39,200 00

Abstract of proposals received and opened June 4, 1877, for improving the harbor at Pentwater, Mich.

	Bidders' names and residences.	Timber.			Piles.		Iron.		Filling.		Driving piles, per linear foot.	Dredging sand, per cubic yard.	Removing slabs, per cubic yard.	Aggregate.
		Pine, per cubic foot.	Oak, 10 by 12 inches, per linear foot.	Oak, 4 by 8 inches, per linear foot.	Oak, per linear foot.	Pine per linear foot.	Drift-bolts, per pound.	Screw-bolts, per pound.	Stone, per cord.	Edgings, per cord.				
1	Squier & White, Grand Haven, Mich	$0 20	$0 40	$0 20	$0 11	$0 6	$0 2¾	$0 5	$7 50	$1 25	$0 14	$0 18	$0 18	$5,957 86
2	Charles S. Barker, Sault Ste. Marie, Mich	26	29	14	18	13	4½	5	8 00	1 50	5	30	30	8,112 12
3	Albert Conro, Milwaukee, Wis	24	30	8	12	10	3	6	8 50	2 50	18	20	20	7,983 19
4	Culbert & Hopkins, Muskegon, Mich	22	30	18	13	9	3	4	7 50	1 50	15	18	20	6,596 03
5	Chicago Dredging and Dock Company, Chicago, Ill	23½	25	8	14	10	5	6	8 50	2 00	15	19	50	8,884 73
6	Robert M. Steel, Saint John's, Mich	30	30	11	14	11	4½	5½	9 00	2 00	20	25	50	9,866 31

Contract awarded to Squier & White, lowest bidders.

B B 6.

IMPROVEMENT OF WHITE RIVER HARBOR, MICHIGAN.

During the months of August and September, with the unexpended balance of the appropriation of 1875, the end crib of the south pier was releveled and reballasted, and some repairs were put upon the north pier.

The United States dredging apparatus removed the wreck of a vessel which had drifted into the channel the previous winter, and dredged and removed 12,480 cubic yards of sand, thus deepening the channel for a distance of 400 feet. This work exhausted the appropriation of 1875.

From the appropriation of August 14, 1876, ($5,000,) an allotment of $1,000 was made in the latter part of September for pier repairs; and with this repairs were commenced on south pile-pier, when the severe storms early in October seriously interrupted the work and endangered the crib-pier, especially the crib upon which the light stands. (This crib lost three courses of its superstructure on the south side and a large portion of its ballast.) Attention was, therefore, bestowed upon the cribs, and the repairs absolutely necessary for their preservation, together with the expense of laying up the dredging apparatus for the winter, exhausted the funds of this allotment without enabling us to do much toward repairing the pile-pier.

This spring it was found that the channel alongside of the south pile-pier, east of the crib-work, had shoaled to 8½ and 9 feet for a length of about 200 feet.

The balance of the appropriation ($4,000) was made available early in May. The work projected for this season is to dredge the shoal places with the Government dredge and overhaul the pier-work to the extent of the available funds.

The dredging apparatus, after receiving necessary repairs and before going to South Haven, opened a channel of 10 feet through this shoal. The overhauling of the piers is deferred till later, when the dredge will return to the harbor about the 1st of September.

A break in the north pile-pier, about midway between the shore-line and end of pier, caused by the collision of a schooner with the piers, was repaired in June.

To continue permanent improvements here, as suggested in the report of 1873, (pier-extension,) will require the unappropriated balance of $31,891.56. This amount can be profitably expended during the next working season.

Original estimate (1866) amounted to $170,630.80. The estimate of 1873 increased these figures. There has been appropriated, since 1867, and to include August 14, 1876, $184,000.

This work is located in the Michigan collection-district, Michigan. It is situated at the White River light-house. The nearest port of entry is Grand Haven, Michigan.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 712; tonnage, 84,331; men, 4,253.
Cleared: Number, 714; tonnage, 84,443; men, 4,264.

Money statement.

July 1, 1876, amount available	$2,080 46
Amount appropriated by act approved August 14, 1876	5,000 00
	7,080 46
July 1, 1877, amount expended during fiscal year	4,150 79
July 1, 1877, amount available	2,929 67
Amount (estimated) required for completion of existing project, (including dredging)	36,891 56
Amount that can be profitably expended in fiscal year ending June 30, 1879	31,891 56

B B 7.

IMPROVEMENT OF MUSKEGON HARBOR, MICHIGAN.

The work at this harbor during the fiscal year, 1876–'77, consisted of repairs, which were partly intimated in last year's report as necessary to be made, and were as follows:

The south pile-pier at the junction with the crib-work, where the entire filling for a distance of 50 feet had washed out, was repaired and refilled. A portion of the superstructure and the stone filling at the outer end of the south pier, which was carried away by a schooner colliding with the pier, was replaced. On both north and south piers some crib-intervals were closed and refilled, and broken, rotten timbers were replaced by new ones. The north crib-pier, near its eastern end, over a distance of 150 feet, an additional course of timber was framed, to bring it nearer to the height of the pier east and west of this lower portion. The north pier-head received a new plank decking and additional stone-ballast. A break in the old slab and log pier east of south Government pier was repaired and secured from further damage in December last. All this work was done by hired labor and open-market purchase with the balance on hand from the appropriation of 1875.

Upon examination of the harbor works in June last, we found that the west end of the south pier had settled about 2 feet since the previous fall, and that the side compartments of the end crib had lost the greater portion of the stone filling. Also, that the southwest corner of this crib was considerably damaged by the collision of a vessel with the pier, and requires a new superstructure at this place. The north pier-head crib, which had kept its good position for several years, had settled badly since last fall, so that the northwest corner is only 20 inches above water, and the superstructure between this and the next crib is broken and disconnected.

The channel of the harbor is in good condition, with an available water-way of about 13 feet between the Government piers.

During the present fiscal year, under the appropriation of August 14, 1876, ($15,000,) two cribs, (each 50′ by 30′ by 26½′,) will be placed in extension of the south pier. A contract with Culbert & Hopkins was entered into the 16th day of June, 1877, for the execution of this work between the 1st of July and 1st of December, 1877.

Needed repairs, as above mentioned, will be made by hired labor and open purchase.

The end of the south pier will rest in 20 feet (or more) of water, and no appropriation is asked for the fiscal year 1878–'79. The balance which will remain from the last appropriation will be sufficient for re-

pairs and to secure the work from damage. The contemplated extension of the south pier, I think, may be delayed without detriment to navigation.

Estimate of 1873 called for $56,000, to which was added (report of 1875,) $2,898.04. Total, $58,898.04. Appropriations since 1873 amount to $50,000.

This work is located in the Michigan collection-district, Michigan. It is situated at the Muskegon light-house. The nearest port of entry is Grand Haven, Michigan.

Statement of vessels entered and cleared during the year.

Entered: Number, 2,162; tonnage 431,134; men, 16,153.
Cleared: Number, 2,143; tonnage, 430,412; men, 16,117.

Money statement.

July 1, 1876, amount available	$6,528 62	
Amount appropriated by act approved August 14, 1876	15,000 00	
		$21,528 62
July 1, 1877, amount expended during fiscal year	3,703 16	
July 1, 1877, outstanding liabilities	8,543 98	
		12,247 14
July 1, 1877, amount available		9,281 48
Amount (estimated) required for completion of existing project		8,898 04

Abstract of proposals received and opened June 4, 1877, for improving the harbor of Muskegon, Michigan.

	Bidders' names and residences.	Timber.		Iron.		Filling.		Aggregate.
		Pine, per cubic foot.	Oak, per cubic foot.	Drift-bolts, per pound.	Screw-bolts, per pound.	Stone, per cord.	Brush, per cord.	
1	Knapp & Gillen, Racine, Wis	$0 21	$0 30	$0 03	$0 05	$8 50	$4 00	$9,176 60
2	Loomis & McKey, Deerfield, Mich	25	27	6	7	11 25	2 50	11,896 41
3	Robert M. Steel, Saint John's, Mich	21	25	3½	4½	8 50	3 00	9,191 80
4	James Corlett, Ludington, Mich	21½	24	4¼	5	8 75	3 00	9,637 22
5	James Caldwell, Fulton, N. Y	22	35	4	10	9 00	3 00	9,771 19
6	Chicago Dredging and Dock Company, Chicago, Ill.	23¼	30	5	6	8 00	4 00	9,735 62
7	Culbert & Hopkins, Muskegon, Mich	21	28	3	4	7 50	3 00	8,543 98
8	John E. Thomes, Chicago, Ill	23½	28	3½	4½	9 25	5 00	10,123 52

Contract awarded to Culbert & Hopkins, lowest bidders.

B B 8.

IMPROVEMENT OF GRAND HAVEN HARBOR, MICHIGAN.

During the season of 1876, some slight repairs in the way of overhauling and refilling defective places were made to the south pier. The head of the north pier, which had been damaged by the schooner Herald, was repaired, and both pier-heads riprapped, leaving them in good shape for the winter.

This spring's examination shows the north pier-head has settled to the northward a very little. The filling in the north pile-pier and revetment has settled considerably for a length of about 900 feet, so as to require attention. The filling in the south revetment also has settled, and in several places is so shaken up by the heavy seas as to require quite an outlay of money to place it in good condition again.

A more uniform depth of water is found now, both between the piers and beyond in the lake, than at any time before. The whole channel-way between the piers is now available for any class of vessels plying the lakes.

The shore-line south of the harbor has receded about 20 feet, while on the north side it is made out about 30 feet uniformly for nearly one-half a mile northward.

Under the appropriation approved August 14, 1876, of $15,000, a contract was made November 25, 1876, with Mr. James Caldwell, to commence May 1, 1877, the construction and placing of three cribs in extension of the north pier, and to complete the work by the 1st of July, 1877.

Work under this contract has progressed very slowly. One crib has been ready to sink for nearly two weeks, but the weather has afforded a partial excuse for its not being in place at this time. Another crib is nearly completed. Both cribs will probably be in position by the 10th of July, and it is expected that the third one will be placed by the end of the month.

Upon completion of this work the pier-heads will be nearly abreast the north pier, a little the longer. A further extension of the north pier I would defer for the present, and therefore this portion of my recommendations of last year is omitted; the balance is renewed, as follows: To continue the revetment on south side, into the bend of the river, at an estimated cost of $14,400; for repairs, including contingencies and superintendence, $3,640. The superstructure of the outer 800 feet of south pier is very much distorted by irregular settlement of the cribs, and will shortly have to be replaced by a new structure. It is difficult to estimate the cost of removal of this old work, but I place it at $500. The new superstructure will cost $9,108.96. Total, $9,608.96.

In 1872 it was estimated that the amount required to complete this harbor would be $233,300.

The recommendations heretofore made embrace for the improvement of the harbor—

Extension of north pier	$32,000 00
Revetment of south side	14,400 00
Repairs, contingencies, and superintendence	3,640 00
New superstructure over old work on south pier	9,108 96
Total	59,148 96
Less last year's appropriation	15,000
Leaves the unappropriated balance at	44,148 96

Total amount appropriated since 1866 to the present date, $279,751. The original estimate (1866) contemplated an expenditure of $352,770.47.

This work is located in the Michigan collection-district of Michigan. Grand Haven is the port of entry. It is situated at the Grand Haven lights.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 867; tonnage, 397,044; men, 10,703.
Cleared: Number, 887; tonnage, 421,544; men, 10,796.

Money statement.

July 1, 1876, amount available	$4,774 23	
Amount appropriated by act approved August 14, 1876	15,000 00	
		$19,774 23
July 1, 1877, amount expended during fiscal year	3,506 12	
July 1, 1877, outstanding liabilities	13,264 72	
		16,770 84
July 1, 1877, amount available		3,003 39
Amount (estimated) required for completion of existing project		44,148 96
Amount that can be profitably expended in fiscal year ending June 30, 1879		27,648 96

Abstract of proposals received and opened November 8, 1876, for improving harbor at Grand Haven, Michigan.

	Bidders' names and residences.	Timber.		Iron.		Filling.		Aggregate.
		Pine, per cubic foot.	Oak, per cubic foot.	Drift-bolts, per pound.	Screw-bolts, per pound.	Stone, per cord.	Brush, per cord.	
1	R. A. Conolly, Chicago, Ill	$0 39	$0 42	$0 07	$0 08	$9 00	$4 00	$19,140 29
2	James Caldwell, Fulton, N. Y	21	35	04	08	9 00	3 00	13,264 72
3	Steel & Smith, Detroit, Mich	23½	23½	04	04½	8 75	3 00	13,739 51
4	Knapp & Gillen, Racine, Wis	32	32	04½	06	10 50	4 00	17,441 79
5	Squier & White, Grand Haven, Mich	24	40	03¾	05	8 75	2 50	13,776 14

Contract awarded to James Caldwell, lowest bidder.

BB 9.

IMPROVEMENT OF BLACK LAKE HARBOR, MICHIGAN.

The encroachment of sand upon the channel through the revetments and into the mouth of the harbor left but 7 feet of water in the channel in September, 1876.

There being no funds available for any extended repairs, the pier-heads were filled with stone and riprapped and so left secure for the winter.

This spring there was found an average depth of only 6½ feet of water between the piers for quite a stretch.

Under the appropriation approved August 14, 1876, a contract has been made with Squier & White to dredge the channel and add one crib to the south pier. During the month of June they have had two dredges employed, and have removed from the channel 14,297 cubic yards of sand. About 800 feet of revetment is to be overhauled and will be filled with brush, built in after the manner adopted in Holland, so as to make it absolutely impervious to sand. Five hundred feet has already been freed of old and worthless filling and in part replaced with 56¼ cords of brush-mats.

It is believed that the work of this season will give to this harbor a depth of 10 feet. The piers, however, rest in 11 feet, and as the current here depends almost entirely upon the winds, a heavy westerly storm will stir up the bottom at this depth and carry the sands into the channel, to be lodged there. The piers should be carried out to the 15 feet curve to secure a depth in the channel of 12 feet, which is but commensurate with the importance of the harbor. An extension of 200 feet to both piers will be required and will cost $32,000.

I attach hereto a couple of letters received, setting forth some of the claims of Black Lake Harbor to be considered as an important national work.

The original estimate for this harbor (1866) amounted to $106,238.04. Appropriations of 1866-'67 covered that amount. Recommendations and estimates, rendered since 1867, for the continuation of improvements here, require the expenditure of $32,000, which amount can be profitably expended during the fiscal year ending June 30, 1879.

This work is located in the Michigan collection-district, Michigan. It is situated at the Holland light, (pier-head light near end of south pier.) The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 226; tonnage, 13,528; men, 891.
Cleared: Number, 224; tonnage, 13,464, men, 861.

Money statement.

July 1, 1876, amount available	$4,281 65	
Amount appropriated by act approved August 14, 1876	15,000 00	
		$19,281 65
July 1, 1877, amount expended during fiscal year	1,608 32	
July 1, 1877, outstanding liabilities	7,191 18	
		8,799 50
July 1, 1877, amount available		10,482 15
Amount (estimated) required for completion of existing project		32,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		32,000 00

Abstract of proposals received and opened June 4, 1877, for improving the harbor at Black Lake, Michigan.

Bidders' names and residences.	Timber.		Iron.		Filling.		Dredging sand, per cubic yard.	Removing stone, per cubic yard.	Aggregate.
	Pine, per cubic foot.	Oak, per cubic foot.	Drift-bolts, per pound.	Screw-bolts, per pound.	Stone, per cord.	Brush, per cord.			
1 Coates & Hutchinson Saugatuck, Mich.	$0 30	$0 35	$0 05½	$0 06¼	$8 00	$3 50	$0 25	$0 60	$9,404 48
2 Albert M. Steel, Saint John's, Mich	23	25	03½	04½	9 00	3 00	25	50	8,593 28
3 Chicago Dredging and Dock Company, Chicago, Ill.	23½	30	05	08	8 00	4 00	19	30	7,005 03
4 Kanters & Son, Holland, Mich	21	30	04	06	9 50	3 00	22	40	7,846 37
5 Squier & White, Grand Haven, Mich	22	40	03	04¼	8 00	2 00	16	16	5,855 59
6 Charles K. Barker, Sault Sainte Marie, Mich.	26	29	04	05	8 00	1 75	28	28	8,442 11
7 Colbert & Hopkins, Muskegon, Mich	22	28	03½	04	8 00	3 00	18	20	6,318 55

Contract awarded to Squier & White, lowest bidders.

COMMERCIAL STATISTICS.

Letter of Mr. Henry D. Post.

HOLLAND, MICH., *July* 4, 1877.

DEAR SIR: As suggested, I will give you some of the points of the claims of Holland Harbor to be considered as an important national work.

PHYSICAL FEATURES.

Black Lake has some physical peculiarities which should be considered. It is the most easterly harbor of the eastern shore of Lake Michigan south of little Pointe Sable, being at the bottom of the great bay of the eastern shore, between that point and the head of the lake. Here the navigable waters of Lake Michigan extend into the great body of heavy loam soil of the bowlder-clay formation, which makes the greatest amount and the best quality of soil of the farming-lands of the lower peninsula of Michigan. West from the entrance to Black Lake is the broadest expanse of water and the greatest depth of Lake Michigan. The coast-line varies so little from a north and south line between the mouths of the Kalamazoo and Grand Rivers, that the coast is seldom, almost never, blocked with ice by southwesterly or northwesterly winds in winter.

RAILROAD CONNECTIONS.

Holland is connected by the Chicago and Michigan Lake Shore Railroad with the Michigan Central trunk line to the eastward, directly *via* the Grand Rapids division, and indirectly to the southward. By the establishment of a shipping connection with

Milwaukee, it would become a point on the shortest possible line connecting Milwaukee with the Michigan Central Railroad system of roads.

The Michigan Lake Shore Railroad connects at Allegan with the Lake Shore and Michigan Southern system of roads, and when the Michigan Lake Shore is consolidated with and becomes a part of the Mansfield, Coldwater and Lake Michigan Railroad, it is then a point on the shortest trunk line between Milwaukee and New York City. The Michigan Lake Shore road also connects Holland with the Pennsylvania Central system of roads, and it is thus an important point in the connection of Milwaukee and the great Northwest with three of the great trunk lines to the Atlantic. Some two years ago the attention of the Board of Trade of Milwaukee was directed to this subject of a new outlet for their eastward-bound freights, and responsible parties proposed to establish a line of boats from Milwaukee to Holland *as soon as the harbor entrance will admit them safely in all weathers.* Several attempts have been made to establish steam-lines from Holland to Chicago, but the unsafe and uncertain condition of the harbor has always been the obstacle to their success which *could not be overcome*

LOCAL BUSINESS.

Holland is the commercial center of the largest, most densely populated, and the wealthiest farming community on the eastern shore of Lake Michigan. Its farming-lands have a deep, strong loam "bowlder-clay" soil, and the finest winter-wheat raised in the Northwest is a staple product. An excellent soil for the cultivated grapes, hay, and dairy-products; are, perhaps, next to wheat, the great staples. It is at the center of the "peach-belt" of the eastern shore, and its soils and climate are unsurpassed for the cultivation of peaches, grapes, and small fruits, while its heavy loam soils are superior to many for the culture of the apple and the pear.

The almost unlimited extension of the business of raising choice fruits for the supply of the western markets has been heretofore hindered for the want of steam transportation to the westward. Here, again, the want of a harbor is the great hinderance to success.

Our manufacturing interests are growing as rapidly as the general depression of business will permit. We probably manufacture more leather than any other town in Michigan. Our tanneries require about 8,000 cords of hemlock-bark, and 100,000 hides; and their products reach the value of some $500,000 per year. They are now compelled by the want of steam-lines by water to transport by rail, although it would be much cheaper and more convenient to ship by water. A large cooperage factory also requires a large amount of lake-transportation of rough stock in and manufactured products outward.

We have within a few miles of Holland five extensive beds of iron-ore, and probably more remain to be discovered. Just at the commencement of the present hard times, a company was organized to build a furnace to manufacture pig-iron. Fortunately, the company had not got too far to suspend operations without loss, and it lies dormant, waiting for better times.

The advantages of the location are such that there is very little doubt that this will become the seat of a heavy iron-manufacturing interest. A furnace on a moderately large scale would require at least 10,000 tons of lake-transportation of stock inward, besides the tonnage of the manufactured iron outward. The ores found here are most valuable to mix with the specular ore from Lake Superior mines, so that at least half the ore smelted will be shipped in from the lake. Limestone for fluxing, and cord-wood for charcoal, must also be imported from Lake Michigan.

LOCAL TRAVEL AND TRAFFIC OF RAILROADS CONNECTING HERE.

With the necessary lines of boats to Milwaukee and to Chicago, the port of Holland would receive the travel and traffic westward of the Michigan Lake Shore Railroad from Monteith, including Allegan and all the intermediate points, a distance inward, southeast, of 35 miles; from the same road, half-way to Grand Haven, 10 miles; from the Chicago and Michigan Lake Shore Railroad, south; from Grand Junction, 29 miles; from north, from Nunica, 20 miles; from northeast, from Grandville, 19 miles. The proprieters of the extensive plaster-beds at Grandville are only waiting for the completion of Holland Harbor to make extensive arrangements for the shipment of their plaster for Wisconsin and Minnesota through here. And we can at least compete on equal terms with Grand Haven for the lake traffic between Grand Rapids and Chicago.

With such a showing, we claim that the harbor of Black Lake, being the port of Holland, must be considered a work, not merely for a local benefit of limited extent, but of national importance, as opening a new channel for the commerce of the great Northwest toward the Atlantic, and that it must become also one of the most important ports on the eastern shore for its local trade with the States west of Lake Michigan.

Very respectfully, yours,

HENRY D. POST.

Captain S. C. MOWER.

Letter of Mr. M. D. Howard.

HOLLAND, MICH., *July* 4, 1877.

DEAR SIR: In reply to your inquiries relating to the resources and shipping requirements of Holland and vicinity, will say that I have seen Mr. Post's statement, which he will forward ere this. But I think he omitted some items of interest that may with propriety be included, to wit: Hemlock-bark has been and would be shipped annually from this port to the extent of from 2,000 to 5,000 cords in excess of the tannery demands, could lake freights be obtained at competing rates. Here one pays $1.50 per cord freight, while other good harbor ports get them at $1. In staves and barrel stock, usually from 250,000 to 1,000,000 staves per annum have supplied our local marine with freights; now they are shut out for want of water. In the matter of the 5,000 to 10,000 cord of wood annually shipped from this port, the trade is largely reduced on account of the advanced rates of shipment, which equal nearly 50 cents per cord, a margin sufficient to secure large shipments, if it could be saved.

Six months would not elapse after we have secured a channel suitable for iron-ore vessels to enter this port before we would have a blast-furnace that would develop the bog-ore that exists in large and paying quantities in the vicinity of Black Lake, which would develop large natural wealth.

The time required to fully develop all that could be said on this port in season for your report compels me to be brief; but we feel under obligations to you that you have given the opportunity to say this much.

Yours,

M. D. HOWARD.

Captain MOWER.

B B 10.

IMPROVEMENT OF SAUGATUCK HARBOR, MICHIGAN.

In the fall of 1876, there was allotted for this work $1,500, from the appropriation of $3,000, approved August 14, 1876, with which to make necessary repairs for preservation of the existing work. This sum was expended, with the exception of $172.44, upon the outer 110 feet of the south pier, which put it in good shape for the winter.

During June, with the unexpended balance of the appropriation, still more ballast was added to this portion of the work, and the outer portion of the pier was decked with 3-inch plank, extending shoreward on the weather (north) side of the pier in a strip 6 feet wide for 224 feet, leaving the work in what is believed to be a permanently good condition.

In the bend of the river, 16 pockets, in which the filling had settled uniformly to below the water-level, were refilled with edgings and ballasted with stone.

The outer end of north pier—the outer 400 feet of which was entirely devoid of filling to a depth of 3 feet below water—was refilled for a distance of 56 feet.

Work has been suspended for the present, as the inspector's services are needed at Black Lake Harbor. The balance of the funds will be expended later in refilling the north pier so far as possible.

The local industries of the country tributary to the Kalamazoo River in the vicinity of Saugatuck have undergone a great change in the last few years. The timber business, which was formerly the absorbing interest, has given way to fruit-culture and farming, which former is rapidly developing into considerable proportions. A line of steamers ply between this port and Chicago direct, and appear to do a good business.

Thirty-eight thousand four hundred and fifty-eight dollars and seventy-four cents have been estimated as necessary to the completion of the

existing project, and I recommend the appropriation of $10,000 for next season.

Total amount appropriated from 1868 to 1876, inclusive, $98,000. Original recommendations call for an expenditure of $136,458.74.

This work is located in the Michigan collection-district, Michigan. It is situated at the Kalamazoo light. The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 332; tonnage, 32,936; men, 2,240.
Cleared: Number, 327; tonnage, 32,687; men, 2,200.

Money statement.

July 1, 1876, amount available	$244 86	
Amount appropriated by act approved August 14, 1876	3,000 00	
		$3,244 86
July 1, 1877, amount expended during fiscal year	1,705 82	
July 1, 1877, outstanding liabilities	1,111 83	
		2,817 65
July 1, 1877, amount available		427 21
Amount (estimated) required for completion of existing project		38,458 74
Amount that can be profitably expended in fiscal year ending June 30, 1879.		10,000 00

B B 11.

IMPROVEMENT OF SOUTH HAVEN HARBOR, MICHIGAN.

The act of August 14, 1876, appropriated to this work $10,000. In September, there was allotted of this $3,500, for repairing the existing work, which was absolutely necessary for its preservation through the winter.

The work comprised the leveling up of the north pier-head, building a plank-beam in the north side of north revetment near the shore-line, where a break existed, refilling and ballasting within, placing brush mats about the end of north pier, upon which a heavy riprap of stone was deposited, and in decking over the piers. This work now stands in good condition.

In the winter a break was made through the south pier, where the cribs join the old slab and log pier, near the shore-line. We had no means with which to prevent an enlargement of the breach, and during the winter and spring it extended to a length of 90 feet. Through it the sea and sand made a clean sweep.

The channel this spring had but 6½ feet of water. Vessels were unable to enter and were obliged to load and unload at the piers.

The balance of the appropriation ($6,500) made available this spring will be expended in closing the gap (above mentioned) and dredging the channel. The work is now being prosecuted with the Government machinery, (dredge and pile-driver,) 5,326.4 cubic yards of sand have been removed from the channel thus far, and the materials for the work are mostly on hand.

The recommendations in my last annual report are renewed, viz, to finish the work of dredging and revetting the north side, which will embrace 250 feet of work, at an estimated cost of $12,000, and to extend both piers 300 feet, (estimated cost $60,000.)

Estimates heretofore made from time to time amount to $202,000. There has been appropriated since 1867 a total of $130,000.

This work is located in the Michigan collection-district of Michigan. It is situated at the South Haven light. The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 234: tonnage, 35,585; men, 1,809.
Cleared: Number, 232; tonnage, 35,002; men, 1,799.

Money statement.

July 1, 1876, amount available	$90 27	
Amount appropriated by act approved August 14, 1876	10,000 00	
		$10,090 27
July 1, 1877, amount expended during fiscal year	4,736 05	
July 1, 1877, outstanding liabilities	1,439 30	
		6,175 35
July 1, 1877, amount available		3,914 92
Amount (estimated) required for completion of existing project		72,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		25,000 00

B B 12.

IMPROVEMENT OF SAINT JOSEPH HARBOR, MICHIGAN.

Eight thousand dollars was allotted to this work last fall out of the appropriation of $12,000 approved August 14, 1876. Of this amount $1,237.69 was expended during the fall and winter. One hundred and twenty-eight cords of stone were purchased, of which 92 cords were used to riprap the north pier and 36 cords placed on south pier, in reserve.

The spring examination develops the necessity for a considerable outlay for repairs, and the balance now on hand should be applied to this purpose this season.

During the spring-blows the end crib of the north pier became undermined, and, with its superstructure, was wrenched from its place, and carried ashore just south of the south pier, where it lies embedded in the sand, in five feet of water.

The seas have combed the stone out of the north pier so as to leave them below water in several places.

The old work inside of the work of 1875 is in a very dilapidated condition, the superstructure being broken in three places, and rotten for quite a distance. The stone is gone to below water in a number of places, and it is thought that all the funds available will be required to put the piers in proper repair.

The filling and stone are out of the south pier for a space about 90 feet long to a little below water on the lake side.

The depth of water remains good.

During the winter Messrs. Culbert & Hopkins got out the material for and framed the crib called for under their contract dated November 28, 1876, and early in May, 1877, took the timbers to Saint Joseph and put them together. The crib was sunk and filled on the 28th of that month. The crib was placed in good alignment and level, and has just been superstructured.

The repair and refilling of the piers is very necessary.

The outer pier (north) should be planked over.

The recommendations and estimates of last year are renewed, namely, to extend the north pier to 16 feet of water, requiring three cribs, estimated to cost $16,261.71. (See Report of Chief of Engineers, part 2, 1876, page 518.)

This work is located in the Michigan collection-district, Michigan. It is situated at the Saint Joseph lights. The nearest port of entry is Grand Haven, Michigan.

Statement of vessels entered and cleared during the year ending June 30, 1877.

Entered: Number, 194; tonnage, 67,960; men, 2,916.
Cleared: Number, 190; tonnage, 67,536; men, 2,900.

SAINT JOSEPH RIVER.

The town of Benton Harbor, as will be seen by the custom-house report of tonnage, is very nearly as considerable as a point of local importance in shipping as Saint Joseph.

The energy and enterprise displayed by the people of this town and vicinity in dredging and maintaining a canal giving them communication with Lake Michigan, would seem to entitle them to a sufficient appropriation to enable them to hold the advantages gained through their own exertions.

A very large money-interest is at stake upon the ability of steam-vessels to make quick trips from this point during the fruit-season, and as the propellers are frequently obliged to dredge a narrow cut with their wheels in order to enable them to pass over the bar at the lower end of the wing-dam, it is respectfully urged that a sufficient amount be appropriated to cover the expense of filling and ballasting the wing-dam, dredging away the bar mentioned, and revetting the Paw-Paw River in extension of the wing-dam 800 feet, which will cost about $15,000.

With the improvements recommended, it is thought that no further expenditure will be necessary, save for such repairs as may be needed from time to time to keep the work in order.

Statement of vessels entered and cleared at Benton Harbor, Michigan, during the year ending June 30, 1877.

	No.	Tonnage.	Men.
Entered	155	46,900	3,162
Cleared	165	47,828	3,236

Money statement.

July 1, 1876, amount available	$365 40	
Amount appropriated by act approved August 14, 1876	12,000 00	
		$12,365 40
July 1, 1877, amount expended during fiscal year	4,309 36	
July 1, 1877, outstanding liabilities	1,048 74	
		5,358 10
July 1, 1877, amount available		7,007 30
Amount (estimated) required for completion of existing project		31,261 71
Amount that can be profitably expended in fiscal year ending June 30, 1879.		31,261 71

Abstract of proposals received and opened November 8, 1876, for improving the harbor of Saint Joseph, Michigan.

	Bidders' names and residences.	Timber.		Iron.		Filling.		Aggregate.
		Pine, per cubic foot.	Oak, per cubic foot.	Drift-bolts, per pound.	Screw-bolts, per pound.	Stone, per cord.	Brush, per cord.	
1	Culbert & Hopkins, Muskegon, Mich	$0 24	$0 30	$0 03¼	$0 06	$8 75	$3 50	$3,367 92
2	Steel & Smith, Detroit, Mich	30	30	4	5	10 00	4 00	3,982 50
3	Knapp & Gillen, Racine, Wis	35	35	5	7	11 50	5 00	4,657 04
4	R. A. Connolly, Chicago, Ill	39	42	7	8	8 50	4 00	4,599 20
5	James Caldwell, Fulton, N. Y	22	30	4	6	9 50	3 00	3,370 86

Contract awarded to Culbert & Hopkins, lowest bidders.

APPENDIX C C.

ANNUAL REPORT OF MAJOR G. WEITZEL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

(Letter of transmittal under Appendix S.)

C C 1,

SAINT MARY'S FALLS CANAL, MICHIGAN.

At the beginning of the fiscal year there were but two contracts in force for the further prosecution of this work.

The one was with Mr. Henry Van Vleck, for furnishing the face stone for the new locks, and the other with Messrs. Boyle & Roach, for furnishing the backing-sand and laying the walls of the same. In order that there may be no doubt whatever about the quality of the mortar to be used, I deliver the cement.

We use the English Portland cement for laying the face-stone and the miter and lift walls, and all portions of the wall adjacent to wet places.

For the remainder of the wall we use American cements, and, so far, chiefly that obtained from the vicinity of Louisville, Ky.

The work made but very slow progress during last season, on account of the slow delivery of the face-stone; but during the present season there has been a great improvement. The amount of face-stone required is a little over 10,000 cubic yards, and the amount of masonry in the walls is about 27,000 cubic yards. At the end of the fiscal year about one-fifth of the face-stone had been delivered and about one-sixth of the masonry laid.

In addition to the operations which were carried on under these two contracts, two other smaller pieces of work were done by day's labor. The one was filling in the area between the south pier at the foot of the new locks and the shore-line.

This pier was built during the preceding year, and there was a considerable area between the inside of it and the shore-line which was covered with water. We filled in this area to the level of the top of the pier and the shore, and we have thus obtained, in close proximity, excellent yard-room for unloading, storing, and handling the large amount of material required in the construction of the new locks. The other consisted in raising the banks of the canal, near its lower end, to a height of from 2 to 4 feet by means of levers. This was done to guard against such events as occurred on the 23d of June, 1876. On the morning of that day the water in the canal suddenly rose to about 4 feet and was running over the banks. If it had not been promptly checked in its flow, the most disastrous results might have occurred at the lower

end of the canal in the destruction of the banks, which are here comparatively weak.

To supply a want which, I understand, has been felt by some of my brother officers of the corps in the various annual reports on this improvement, I introduce here a brief historical and descriptive sketch of the work, which by my direction was prepared by my civil assistant on the work, Mr. Alfred Noble. Mr. Noble has occupied his present position ever since the enlargement was begun.

This sketch is illustrated by five plates, which I hope may all be published with it in the annual report of the Chief of Engineers. It is as follows, viz:

The Saint Mary's Falls Canal is situated near the village of Sault Ste. Marie, Mich., at the principal rapids in the Saint Mary's River. This river or strait is the outlet of Lake Superior. The canal is 15 miles from Lake Superior and 60 miles from Lake Huron by the navigable channel of the river.

The rapids at this point are a little more than one-half mile in length, and have a fall of from 16½ to 18¼ feet, depending upon the stages of water in the lakes which the river connects; the mean fall being very nearly 18 feet. From Lake Superior to the rapids the fall is only one-tenth of a foot; from the rapids to Lake Huron the fall is about 2 feet, distributed through a distance of 20 miles. These rapids, the Sault de Ste. Marie, are therefore the only impediment of this nature obstructing navigation between the lakes.

The commerce of Lake Superior before the year 1845 was almost entirely in furs; at that time the development of copper and iron mines was commenced, and the rapids at this place were found to be a serious obstacle in the way of the successful prosecution of these enterprises. The products of the mines, the appliances for working them, and the supplies for the laborers had to be unloaded from the vessels on which they were brought here, transported past the rapids, and reshipped. Finally, in 1850, a grant of 750,000 acres of land was made by act of Congress to the State of Michigan to defray the cost of constructing a canal past the rapids.

In 1853, the legislature of the State having accepted the grant and authorized the construction of the work, a contract was made by commissioners appointed by the governor, with a company who undertook to build the canal for the land-grant. The work was commenced soon after the opening of navigation in that year, and on the 18th of June, 1855, the completed canal was opened to navigation. In its construction the company had expended about $1,000,000. In view of the large amount of capital required, no return being possible until after the sale of the lands, the isolation of the locality, inaccessible during five months of the year, and the severity of the climate, which greatly retarded work during winter, the rapid construction of the canal was a remarkable feat.

This was about the first ship-canal made in the United States. The locks and gates were the largest made in the country up to that time. The depth of water was the greatest that had been called for in any similar American work. The engineering features were thus without precedent in American practice, but they were well worked out, and the canal has proved to be a very successful one.

As originally built, the canal was 5,400 feet long, had a width of 100 feet at the water-line, with slopes of ½ to 1, paved where the cutting was not through rock, and a depth of 12 feet at mean stage. The locks located near the foot of the canal were two in number, combined, each 350 feet in length, 70 feet in width, with a lift of 9 feet. The walls were of limestone, obtained from Marblehead, Ohio, and Malden, Canada; the backing from Drummond's Island, near the mouth of the Saint Mary's River. The face-stone were laid in regular courses, with irregular bond; had bush-hammered faces with 1½ inch margin draft, and joints had beds cut to ⅜ inch. The general plan of the masonry is shown in Plate III.

It is not known that rock was reached anywhere in the excavation for the locks at the grade required for the floor. The walls were laid on a floor which extended across the chambers.

The floor was made of timber and plank, the timbers laid across the pit, with spaces of 6 inches or 1 foot between them, and covered with two courses of plank. There is a longitudinal string-timber under the floor under the face of each wall, and two others near the center of the lock; wherever the excavation reached nearly to the rock, trenches were made to the rock on the sites for the last two timbers, and timber walls, 1 foot thick secured to the rock with fox-wedged bolts, were built from the surface of the rock to the required grade.

The gates were of wood; the girders were built beams framed into quoins and miter-posts and trussed with iron tie-rods. On Plate IV is a drawing of one of the gates

about to be placed between the locks, differing only in a few minor details from the original ones.

Each gate is opened by a line and closed by a boom. The power, manual labor, is applied through a capstan on the wall. Both the line and the boom are attached to the top of the gate at the miter-post. This gear is decidedly primitive, and seems objectionable, inasmuch as the strain is applied at that part of the gate farthest from the center of resistance; but it is simple, and easily and quickly repaired; the fact that the original gates stood and were operated without accident or delay for more than 20 years shows that they never have sustained serious injury from any cause. Each gate is supported on a pivot resting on the floor of the lock and entering a socket in the foot of the quoin-post, and is suspended from a tower 7 feet in height, resting on the coping at the hollow quion. There is no roller at the miter-post. The gates are opened or closed in from three to four minutes.

Near the bottom of each gate are six openings, each 2 by 4 feet, for the admission or escape of water; each opening is closed by a cast-iron butterfly-valve, operated by a rack and pinion at the top of the gate. Each lock is filled or emptied in about 7 minutes.

At the foot of each wall a check was made to receive the end of a caisson-gate, which rested also against a sill laid across the floor. This was to be used in case it should be desired to pump out the lock, but does not fulfill its purpose, because the water passes under the floor and comes through it above the caisson-sill.

At the head of the canal was placed a guard-gate, with its appropriate masonry. The opening was 70 feet. The gate was a caisson, hinged at one end, and of sufficient length to close the opening. This was found inconvenient, and in 1862 a pair of ordinary lock-gates, with the proper masonry, was placed farther down the canal in the position indicated in Plate I.

The entrances to the canal were revetted with piers. The south piers were built originally as shown in Plate I, no extension having been made up to the time of commencing the improvements. The north piers originally extended only to the shore lines, but were lengthened subsequently.

At the time the canal was made it was deemed of sufficient capacity in every way to meet the needs of navigation. The depth was sufficient to pass any vessel on the lakes fully laden. The locks were large enough to contain a tug and three vessels of ordinary dimensions, which generally constituted a tow. By the year 1870 these dimensions no longer sufficed. Vessels were larger and were not able to carry full loads on 12 feet of water; only one of the larger vessels could be passed at one lockage, and the number of vessels engaged in the Lake Superior trade had increased so greatly that they were frequently delayed several hours. It became necessary to provide for more rapid lockage and for the passage of larger vessels. The slope-walls had been found objectionable, vessels coming in contact with them below the water-line and sustaining injuries. In July, 1870, Congress made an appropriation for commencing the improvements. In August, 1870, a project was submitted by Maj. O. M. Poe, Corps of Engineers, and received the approval of the Chief of Engineers. The project, after some amendments, embraced the following improvements:

A new lock was to be built opposite the old locks, parallel to them, at a clear distance of 100 feet.

The guard-gates, with their masonry, were to be taken down and replaced 700 feet farther up the canal, and at a lower level.

Entrances to the new locks were to be formed, the lower entrance by excavating out to deep water and reveting the channel with pier work, the upper entrance by widening the canal from the new position of the guard-gates, where the original width was retained, eastward so until it became wide enough to open the way to both the old and new locks.

The slope-walls were to be removed and a timber revetment, with a face nearly vertical, substituted, where the cutting was through rock, the revetment was placed on the first sound rock reached; below the base of the pier the rock was cut to a slope of 1 horizontal to 4 vertical; where no rock was found, the revetment was to be built from the grade of improved canal-bottom.

The improved canal was to be made 3½ feet deeper than before the improvements were taken in hand.

The walls of the old locks are to be prolonged up stream to receive a pair of guard-gates.

At the time the canal was made danger was apprehended that ice might be driven into the canal in the spring to such an extent as to delay its opening for navigation. To guard against this, a curve was made near the upper end, so that the direction of the canal above the curve was nearly normal to the direction of the current in the river, which is rapid. This renders the entrance rather difficult for a single vessel and impracticable for a tow of three or more. It is now known that there is no danger of delay by ice. The south side of the canal will therefore be straightened and the pres-

ent south pier above the bend removed. The new south pier will be extende out, as shown on Plate II.

The chamber of the new lock will be 515 feet long and 80 feet wide. The the gates will be 60 feet. A pair of guard-gates will be placed at each end of t ber. The lift of the lock will be 18 feet; the depth of water on the miter-sills The miter-sills are to be placed 1 foot below canal-bottom, so as to be protec injury by vessels.

The foundation is on rock throughout. The rock is a sandstone of different of hardness, some layers being very friable so as to be excavated easily wit and shovel, some exceedingly hard. A floor of timber and concrete was made ing across the bottom of the lock and 5 feet under each wall.

The lock will be filled through two culverts under the floor, each 8 feet cross-section and extending the length of the lock; the water will enter the lock numerous small openings in the top of the culverts. It will be emptied thro shorter culverts under the lower lock-gates. The floor and walls of the culv of timber.

The gates and valves in the culverts will be operated by water-power.

After the completion of the new lock it is proposed to remove the guard-ga the head of the canal, and erect in their place a movable dam.

At this time the guard-gates have been moved 700 feet above the location sl Plate I. The canal has been deepened and widened, the slope-walls removed, timber revetment built (except the work for straightening the south bank of th from the upper end to the basin. On the north side of the canal the slope- been removed and the pier-revetment completed to the head of the old locks. for the south side of the lower entrance has been completed to within 200 fee end of the lock-wall; the lock-pit has been excavated, the culverts and floor an 4,000 yards of the masonry laid.

The excavation from the head of the canal to the basin was principally In excavating the lock-pit rock was reached at from 1 foot to 15 feet above th of lock-floor.

Until May 1, 1873, the work was under the charge of Maj. O. M. Poe, of the Engineers; since that time it has been under the charge of Maj. G. Weitzel Corps of Engineers.

It seems proper for me to add to this sketch that the original was designed and begun under the superintendence of the late Augustus Canfield, Corps of Topographical Engineers.

The appropriation of $130,000, made by the act approved Aug 1876, for continuing the improvement, was made available by from the Chief of Engineers dated May 1, 1877. A project expenditure was submitted and approved. It included dredging head of the canal, with a view to straightening the south bank t

Bids for this were opened on June 20, 1877, and the contract aw to Charles S. Barker, of Sault Ste. Marie, Mich., he being the responsible bidder.

The last passage through the canal in 1876 was on December 4, first passage through in 1877 was on May 2.

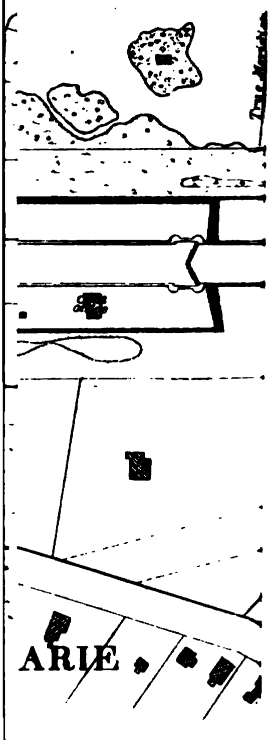
During the year 54,637 cubic feet of cut-face stone have been deli 113,373 cubic feet of masonry laid, and 6,409 barrels of cement purc

The work will be prosecuted during the present working season the three contracts above referred to. If nothing unforeseen o fully two-thirds of the face-stone will be delivered, one-half of th sonry of the new locks laid, and all of the dredging at the head canal done at the end of the present working season.

The operations contemplated in the fiscal year 1877–'78 are to the new locks toward completion, and to begin the pier revetme the south side of the head of the canal.

In order to complete this work according to the project there re to be appropriated the sum of $570,000.

For the sake of an economical and rapid prosecution of the work sum of $300,000 should be appropriated for the fiscal year ending 30, 1879.


ARIE

The whole amount appropriated since the enlargement of this canal was begun is as follows, viz:

1870	$150,000 00
1871	350,000 00
1872	300,000 00
1873	200,000 00
1874	200,000 00
1875	200,000 00
1876	130,000 00
Total	1,530,000 00

Of this amount about $600,000 was expended before and during the excavation of the pit for the new locks, in widening and deepening the canal proper, revetting the sides of the enlarged canal, purchase of additional lands, and in improving Saint Mary's River. Of the other $930,000 about $520,000 have been expended on the lock-pit, walls, and other portions pertaining to the new locks, and about $410,000 were on hand at the end of the fiscal year.

In exact figures this amount was $410,213.06. But all of this sum, except $30,000, is covered by liabilities under the contracts, and is therefore not available for the work which still remains to be done, and should be commenced as soon as possible.

An abstract of bids, received on June 20, 1877, for dredging at the head of the canal, is attached and forms part of this report.

The work is situated in the Superior collection-district, Michigan, at the Sault Ste. Marie subport of entry, and a short distance from Fort Brady. The nearest light-house is at Round Island, and the nearest port of entry is Marquette, Mich. The amount of revenue collected in the Superior district during the last fiscal year was, in coin, $2,026; in currency, $8,415.

The whole commerce of the great chain of northern and northwestern lakes will be benefited by the completion of this work.

Money statement.

July 1, 1876, amount available	$397,227 93
Amount appropriated by act approved August 14, 1876	130,000 00
	527,227 93
July 1, 1877, amount expended during fiscal year	108,213 84
July 1, 1877, amount available	419,014 09
Amount (estimated) required for completion of existing project	570,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	300,000 00

Abstract of bids opened by Maj. G. Weitzel, Corps of Engineers, on June 20, 1877, in accordance with advertisement dated May 15, 1877, for dredging at upper entrance to the Saint Mary's Falls Canal, Michigan.

Names.	Residences.	Price per cubic yard.
Charles S. Barker	Sault Ste. Marie, Mich	$0 16
Larkin & Stickney	East Saginaw, Mich	19
Williams & Upham	Houghton, Mich	27

C C 2.

HARBOR OF REFUGE, LAKE HURON, MICHIGAN.

The work on this improvement was continued during the past fiscal year with the appropriation of $100,000 made by act of Congress ap-

proved March 3, 1875, and the one of $75,000 made by act of Congress approved August 14, 1876.

Mr. Hervey S. Dale, the contractor under the first of these appropriations, completed his contract dated June 21, 1875, during the last season, and final payment was made to him last January.

Under the second of these appropriations work is now being prosecuted at two points. One of the contracts is with Messrs. Hemenway & Hayes for constructing the breakwater, and the other is with Mr. Charles S. Barker for removing the wreck of the *City of Buffalo* and several dangerous bowlders which lie in the harbor.

The annual report of my assistant, Capt. A. N. Lee, Corps of Engineers, who is in special charge of this work, shows the history and progress of the work during the past fiscal year. Mr. C. P. Gilbert, whose name he mentions in his report, is the civil assistant on duty at the work.

There is no reason why, with ordinary good fortune, both of the two contracts now in course of execution should not be completed during the present season. During the remainder of the fiscal year ending June 30, 1878, nothing more can be done for want of funds.

Captain Lee in both of his last two annual reports to me invites attention to the opening left in the shore-arm of the breakwater.

The breakwater which will make this harbor of refuge is being constructed by me at the site and according to the general plan recommended by the Board of Engineers constituted by paragraph 2, Special Orders No. 136, dated Headquarters Corps of Engineers, Washington, D. C., October 12, 1871, in their report to the Chief of Engineers, dated Detroit, Mich., October 12, 1872, and published on page 292, Report of the Chief of Engineers for 1873.

The breakwater as designed by them consists of a shore-arm and a sea-arm. The shore-arm begins at a point near shore in 5½ feet of water, and runs in an east-southeasterly direction about 2,100 feet to the angle in about 23 feet of water. From this point the sea-arm begins and runs in a southeasterly direction in an average of about 30 feet of water. The whole of the shore-arm is completed, and when the present contractors get through there will be 2,310 linear feet of the sea-arm completed.

The Board discussed the question of leaving an opening in the shore-arm sufficient to admit the passage of vessels, and thought it best not to make such a provision on account of the sea, which would surely roll through such an opening at a time when the shelter would be most needed, but stated that the result of this would be to compel any sailing-vessel to tow out when the wind changes to a direction which will admit of her pursuing her voyage.

It was concluded to try this question practically, and in building the shore-arm an opening 300 feet wide was left, beginning at a point 300 feet from the angle of the breakwater. There was no risk and but a trifling additional expense in doing this. It can be closed at any time, if it should be decided to do so.

Mr. Gilbert has all along been of the opinion that it is a great benefit to the vessels using the harbor, and has strongly recommended its retention. Captain Lee was strongly opposed to this view last year, but now seems to have almost completely changed his opinion. I think that we should have the experience of one or two years more, or even longer, before positively deciding what to do. In fact there will be no harm in postponing this question until the whole sea-arm of the breakwater is completed.

The Board, from all the data which were at its command, submitted the following estimate of the cost of this work, viz:

4,000 linear feet of breakwater of maximum section, at $222 per linear foot..	$888,000
3,000 linear feet of breakwater of varying section, at an average of $120 per linear foot	360,000
7,000 linear feet of iron-sheathing, at $10	70,000
25 mooring-rings and attachments, at $100	2,500
	1,320,500
Add 10 per cent. for contingencies	132,050
Total	1,452,550

In other words, the cost per running foot of breakwater of maximum section, including iron sheathing and contingencies, was estimated at $255.20, and the amount of such at 4,000 linear feet. The amount of breakwater of varying section was estimated at 3,000 linear feet and its cost at $143 per foot, sheathing and contingencies included.

Now the true amounts will be when the work is completed, 4,300 feet of maximum section and 1,500 feet of varying section. The latter is entirely completed, and 2,610 feet of the former will be when the existing contracts are completed. The actual cost of the 1,500 linear feet of breakwater of varying section was $75,000, everything included, and 2,610 feet of maximum section will cost $450,000, the removal of the bowlders in the harbor and the wreck of the *City of Buffalo*, and everything else included.

To show the difference between the estimated and actual cost more distinctly, I have constructed the following table, viz:

	Estimated cost.		Actual cost.		Difference.
	Per ft.	Total.	Per ft.	Total.	Total.
1,500 linear feet of breakwater, varying section	$143 00	$214,500	$50 00	$75,000	$139,500
2,610 linear feet of breakwater, maximum section	255 20	666,072	172 42	450,000	216,072
Total	....	880,572	....	525,000	355,572

The amount of breakwater yet to be built, after the funds which are now on hand are exhausted, if the shore-arm opening is not closed up, is 1,690 linear feet of maximum section. Supposing the cost of this to be the same as the average of that which has already been constructed, *i. e.*, $172.42 per foot, we have $291,389.80, or, in round numbers, $300,000, to complete the work according to the present project.

If it is decided to close the opening in the shore-arm, there will be 300 linear feet additional of breakwater, with varying section, which will cost on an average $125 per foot, or a total sum of $37,500. In this case the total sum required to complete the work according to the present project will be, in round numbers, $330,000, and the total cost of the work will have been $855,000, instead of $1,452,550, as originally estimated.

In conclusion, I beg most earnestly to call the attention of Congress and the Chief of Engineers to a matter which led to the correspondence of which the following is a copy:

UNITED STATES ENGINEER OFFICE,
Detroit, January 31, 1876.

GENERAL: I have the honor to submit herewith a draught of an act which it is imperatively necessary should be passed by Congress for the government of the Harbor of Refuge, Sand Beach, Lake Huron.

Very respectfully, your obedient servant,

G. WEITZEL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

AN ACT for the government and control of the Harbor of Refuge at Sand Beach, Michigan.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the passage of this act, and until the completion of the work of construction, the Secretary of War is directed to assume full control over the Harbor of Refuge on Lake Huron, at Sand Beach, Mich., now in course of construction by the United States Government, and of the piers, breakwater, docks, wharves, buildings, and other improvements made by the United States appertaining to said Harbor of Refuge, and to facilitate the use thereof, including the channels of, and approaches to, said Harbor of Refuge, so far as may be necessary to the protection and use of said harbor and the improvements aforesaid; and said Secretary of War, for the purpose aforesaid, and for the preservation of said harbor in the interests of commerce, shall prescribe such regulations not inconsistent with the laws of the United States respecting the use of said harbor and its channels, and the approaches thereto, and respecting the use of the piers, breakwaters, docks, wharves, buildings, and other improvements of said harbor, made by the United States, as he shall deem needful to fully protect and preserve the said harbor and its several channels and approaches, and the said piers, breakwaters, docks, wharves, buildings, and other improvements. Such regulations shall be promulgated by publication thereof for ten days consecutively in one daily newspaper published in each of the cities of Detroit, Buffalo, Cleveland, and Chicago, and said regulations may be changed in like manner from time to time. He shall also cause four copies of such regulations to be kept posted in conspicuous places on said piers and breakwaters.

SEC. 2. The Secretary of War shall appoint, upon the recommendation of the engineer officer in charge of the work, a custodian of said harbor and the improvements aforesaid, whose duty it shall be to preserve and protect the same under the regulations made as aforesaid by the Secretary of War, and to enforce the observance of said regulations, and to guard and preserve the property of the United States at said Harbor of Refuge. Said custodian shall also have power to direct and regulate the stationing and anchoring of steam-vessels and water-craft in said harbor, and the mooring thereof at the piers, breakwaters, docks, and wharves of said harbor, and the laying out and discharging of cargoes and ballast in said harbor piers, breakwaters and docks; and it shall be the duty of said custodian to report to the United States district attorney for the eastern district of Michigan all violations of this act and of the said regulations prescribed by the Secretary of War; and said custodian shall receive such compensation, not exceeding one hundred and fifty dollars per month, as the Secretary of War may allow.

SEC. 3. It shall be the duty of all persons using or navigating said harbor, its channels and approaches, or using any of the piers, breakwaters, docks, wharves, or other improvements made by the United States, to observe the regulations prescribed by the Secretary of War as aforesaid, and any person who shall willfully or negligently strand or sink any steam-vessel, boat, or craft in said harbor, or in the channels or approaches, or who shall willfully obstruct or oppose the custodian of said harbor in the enforcement of the regulations aforesaid, or who shall willfully or negligently or by failure or neglect to observe the regulations prescribed by the Secretary of War for the use thereof, obstruct or impair said harbor, or cause any impediment, injury, filling up, or shoaling therein, or shall deposit any earth, ashes, stone, ballast, or other substances in said harbor, channels, or approaches, tending to obstruct or impair the navigation thereof, or who shall willfully damage or injure the piers, breakwaters, wharves, docks, or other improvements of said harbor, made by the United States, or who shall fail to obey and observe any of said prescribed regulations, shall be liable to a penalty of not less than fifty dollars nor more than five hundred dollars, to be recovered by information or by action of debt in the district court of the United States for the eastern district of Michigan, with costs of suit, and shall, in addition thereto, be liable to the United States, or to any person aggrieved by such obstructions, or injuries, or unlawful acts or omissions, in a civil action for all damages occasioned thereby, or by any of said unlawful acts, to said United States or such aggrieved person. And if such damage or injury to said harbor, channels, approaches, piers, breakwaters, docks, wharves, and other property of the United States, in said Harbor of Refuge, be committed by any steamer, vessel, or water-craft, or by the master or persons in charge thereof, or if such master or other persons in charge of such vessel shall willfully violate the regulations aforesaid, the aforesaid penalty of not less than fifty dollars nor more than five hundred dollars shall be incurred, and such vessel shall be liable for the penalty aforesaid, and may be proceeded against by way of libel for the recovery thereof in any court of the United States within whose jurisdiction such vessel may be found.

SEC. 4. The Secretary of War may, in his discretion, purchase a steam-launch, to be stationed at and used about said harbor, under the direction of said custodian, for the purpose of enforcing the provisions of this act, and such a sum as may be necessary, not exceeding three thousand dollars, is hereby appropriated for the purchase of said steam-launch, and the expense of removing and maintaining said launch shall be paid out of the appropriation made for said Harbor of Refuge.

SEC. 5. After the completion of said harbor by the United States Government the control shall be transferred to the Secretary of the Treasury.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., February 10, 1876.

SIR: Your letter of January 31st last, submitting draft of an act for the government and control of the Harbor of Refuge on Lake Huron, at Sand Beach, Mich., has been received. While there is no doubt that the passage of the act would greatly conduce to the interests of the United States in the work of constructing and governing the Harbor of Refuge at Sand Beach, the reasons that render its passage necessary should be given. You will please, therefore, state the facts and condition of things upon which your opinion of its imperative necessity is founded, in order that the Chief of Engineers may be enabled, when called upon, to furnish such information as may be required by the committee of Congress having the matter in charge.

By command of Brigadier General Humphreys.

Very respectfully, your obedient servant,

JOHN G. PARKE,
Major of Engineers.

Maj. G. WEITZEL,
Corps of Engineers.

UNITED STATES ENGINEER OFFICE,
Detroit, February 12, 1876.

GENERAL: In reply to your letter of February 10, 1876, I have the honor to say that the necessity for the control of the Harbor of Refuge at Sand Beach, Mich., by the Government is shown by the experience of the past season, during which boats and vessels persistently crowded together and made fast to the breakwater in such a manner as to interfere with the work of construction and the use of the harbor by other craft. Rafts entered the harbor to the imminent risk of vessels at anchor, in one case compelling a vessel to slip her cables and leave the harbor during a gale. Steam-craft persistently deposited cinders and other refuse inside the harbor. The increasing use of the harbor will aggravate these evils unless stopped by Government control. In general, a control of the Government is necessary to protect the work and the craft using the harbor.

I am, general, very respectfully, your obedient servant,

G. WEITZEL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

I am not aware that any harbor exists anywhere which is much used by vessels that has not a master to regulate the vessels when they use it. Now, if this is necessary at places where everything comes along and takes position in some order and regularity, how much more imperative is it here, where vessels of all classes and kinds, and rafts, also, enter pell-mell, and are suddenly transferred from a rough sea to smooth water.

It is an imperative necessity that a harbor-master, with full power, be appointed here, if the work shall serve the purposes fully for which it was designed.

I know that there are many vessels now whose masters risk their chances in a storm rather than the risk of being damaged by collision in the harbor.

As stated in a previous part of this report, the estimated cost of this work was $1,452,550, but it will probably not cost more than $855,000. Of this amount the following sums have been appropriated by Congress:

1871	$100,000 00
1872	100,000 00
1873	75,000 00
1874	75,000 00
1875	100,000 00
1876	75,000 00
Total	525,000 00

Now, as only $330,000 is required to complete the work, it certainly would be economical and prudent to take advantage of the present period so favorable in the cost of labor and material, and end it. I therefore recommend that the sum of $330,000 be appropriated for the completion of this work.

Abstracts of bids received on November 11, 1876, for continuing the construction of the breakwater and removing the wreck of the *City of Buffalo* from the harbor are annexed and form part of this report.

This work is located in the collection-district of Huron, Mich. The nearest port of entry is Port Huron, Mich A light-house stands on the angle-crib of the breakwater. The amount of revenue collected in this district during the fiscal year was, in coin, $146,675.20; in currency, $21,870.64.

The whole commerce of the great chain of northern and northwestern lakes will be benefited by this work.

A sketch showing the position of the breakwater and the progress of the work thereon is annexed to this report.

Money statement.

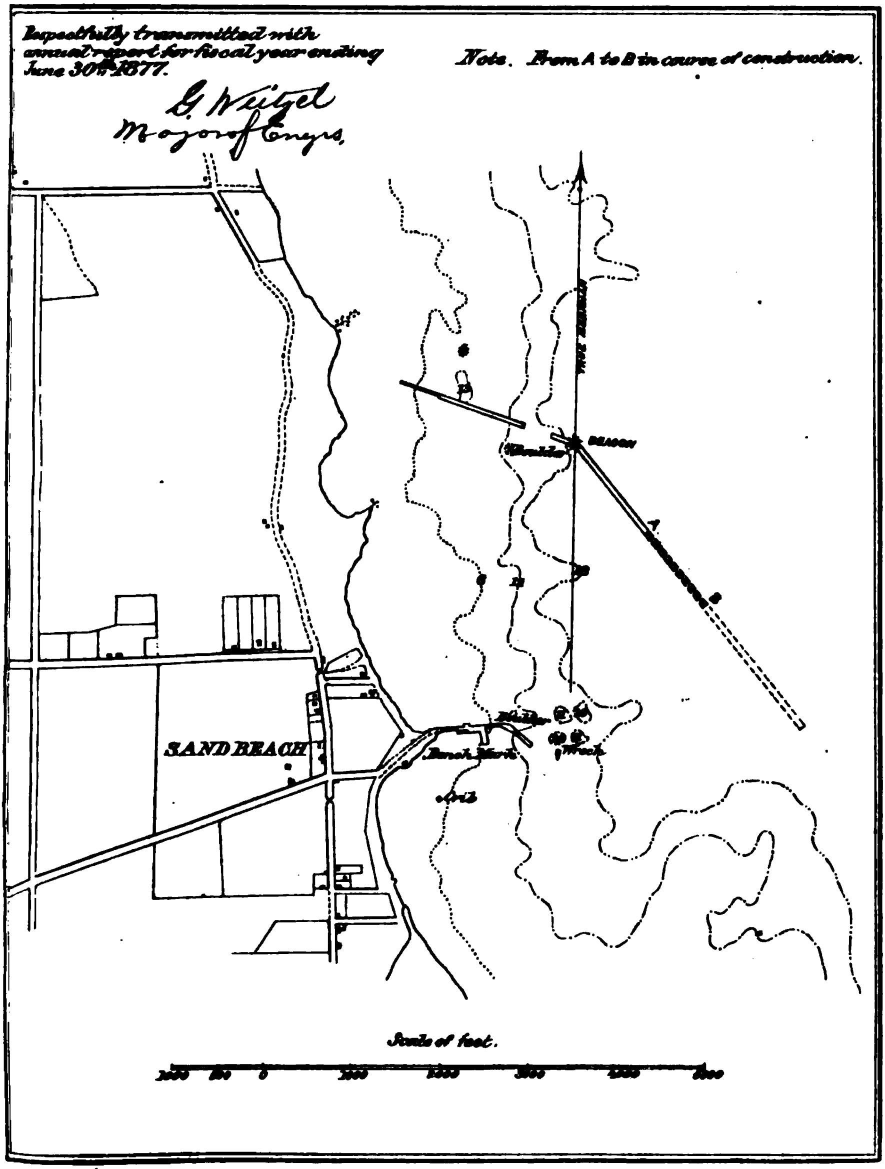
July 1, 1876, amount available	$96,698 74
Amount appropriated by act approved August 14, 1876	75,000 00
	171,698 74
July 1, 1877, amount expended during fiscal year	95,373 94
July 1, 1877, amount available	76,324 80
Amount (estimated) required for completion of existing project	330,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	330,000 00

Abstract of bids for continuing work of improvement of the harbor of refuge, Lake Huron, Michigan, opened by Major G. Weitzel, Corps of Engineers, on November 11, 1876, in accordance with advertisement dated October 10, 1876.

Number.	Names of bidders.	Residences.	Pine, 1,300,000 feet.	Oak, 6,700 feet.	Iron, 118,000 pounds.	Stone, 4,000 cords.	Framing, 1,300,000 feet.	Total.
			Per 1,000 *ft.*	*Per* 1,000 *ft.*	*Per lb*	*Per c'd.*	*Per* 1,000 *ft.*	
1	Hemenway & Hayes	Painesville, Ohio	$13 00	$14 00	$0 03¼	$6 00	$7 75	$54,903 80
2	Farris & Garfield	......do	13 75	18 00	03	5 95	7 50	55,085 60
3	Hervey S. Dale	Chicago, Ill	12 00	20 00	03½	6 00	9 00	55,564 00
4	Steel & Smith	Detroit, Mich	13 00	30 00	03¼	6 50	8 50	57,986 00
5	Robert J. Hackett	......do	13 00	25 00	03¼	6 50	8 50	58,247 50
6	Charles S. Barker	Sault Ste. Marie, Mich.	16 00	18 00	03¼	6 00	8 00	59,155 60
7	Roys J. Cram	Detroit, Mich	19 00	30 00	04½	9 00	9 50	78,561 00

Abstract of bids for removing the wreck of the schooner City of Buffalo and bowlders from the harbor of refuge at Sand Beach, Lake Huron, Michigan, opened by Major G. Weitzel, Corps of Engineers, on November 11, 1876, in accordance with advertisement dated October 10, 1876.

Number.	Names of bidders.	Residences.	Removing wreck.	Removing bowlders, per cubic yard.	Total.
1	Charles S. Barker	Sault Ste. Marie, Mich	$1,500	$3 00	$1,650
2	Hemenway & Hayes	Painesville, Ohio	2,200	8 00	2,600
3	E. P. Harrington	Detroit, Mich	2,100	12 00	2,700
4	H. S. Dale	Chicago, Ill	3,100	15 00	3,850
5	Williams & Upham	L'Anse, Mich	5,000	15 00	5,750
6	Roys J. Cram	Detroit, Mich	3,950	39 00	5,900
7	Hiram Hill	Cairo, Ill	5,000	20 00	6,000


Respectfully transmitted with annual report for fiscal year ending June 30th 1877.
G. Weitzel
Major of Engrs.
Note. From A to B in course of construction.
BEACON
SAND BEACH
Scale of feet.

REPORT OF CAPTAIN A. N. LEE, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Detroit, July 5, 1877.

MAJOR: I have the honor to submit the following report on the continuation of the construction of the breakwater at Sand Beach, Mich, for the year ending June 30, 1877. At the time of my last annual report the contractors were at work under the contract of June 21, 1875.

It was proposed to expend the entire amount available under this contract in the sinking of cribs and to allow them to settle during the winter before putting in any superstructure. This plan was carried out. Nine cribs, 38 by 65, have been sunk and filled during the year. An examination of the work in April last showed that no appreciable damage had been caused by the winter's storms. The cribs have settled slightly but quite regularly along the lake wall. A small quantity of stone has been washed out, and in some places the upper timbers have been cut and broken by the ice. This was no more than was expected, and the damaged timbers will be easily replaced before putting in the superstructure. On the inshore breakwater no effect from ice is noticeable, except an apparent starting of the plating in some places.

A slight damage to the outer wall of the breakwater near the light was occasioned by a vessel running into it under full headway. The master of the vessel supposed the light to be at the opening, instead of on the angle-crib. To prevent a repetition of such accidents, I have had a red light placed on either side of the opening. This should enable vessels to use the opening at night as well as in the day-time. During the season's work, owing to storms, and there not being sufficient quantity of ballast-stone on hand, two of the cribs parted (one at the 11-inch and the other at the 6-inch course) and came up. By means of divers, however, the projecting bolts were cut off, the upper portions lowered to their places and securely bolted. They are apparently as strong now as the others. The last crib under the contract was settled and the final estimate given November 1. At present the work is being carried on under contract of December 4, 1876.

Owing to the unusual quantity of ice in Lake Huron which remained till the first part of May, the contractors were not able to do much work before June 1. They are fairly started now, and have already in place nearly half the superstructure walls, besides a quantity of timber framed ahead. They have also built and launched two grillages. The contractor for the removal of the wreck of the *City of Buffalo* and bowlders has been at work since June 4. He has already removed 15 large bowlders, leaving but two remaining.

The work on the wreck has been somewhat delayed owing to the breaking of the dredge, which necessitated her being sent to Detroit for repairs. The ore, however, has been dredged out, and the hull blasted down so that it can soon be removed.

In order to compare the resistance of the breakwater with the force of the waves to which it may be subjected, and to ascertain, if possible, if this force increased or diminished as the work was carried farther into the lake, Mr. Gilbert, during the spring, designed a form of marine dynamometer which it is proposed to use during the present and coming seasons.

Three of these are already in position at intervals along the lake wall, but they have not been in position long enough yet to warrant a report on their merits. Mr. Gilbert has taken advantage of the presence of a diver at Sand Beach to use his diving-suit on several occasions to make an examination of the different portions of the work. He says:

"A personal examination, in divers' armor, of the crib-walls below water has shown that on the cribs that parted last season the two portions have not separated in settling. The end crib, although now safely settled, is not in the condition reported by the diver who put it together. I found along the outside wall a number of large holes under the cribs, which, on a less stable bottom, would endanger the work. Should the slightest tendency to further settlement appear at these points, the holes should be at once filled, either by dumping a considerable quantity of small bowlder-stone along the wall, or by placing the stone now on the bottom carefully under the crib-wall. I think the latter method would be cheaper and give the best result. A break in the superstructure that would allow the water from heavy seas to flow down through the crib and out the bottom would almost certainly cause a settlement and canting of the cribs at these points. Aside from these points, I do not see any necessity for riprap. I do not think it would be an excessive precaution to repair this the present season. Frequent submarine examinations of the bottom as the work progresses will tend very largely to prevent the irregular settlement and canting that we have had to contend with, and, by showing exactly where riprap is needed, will reduce that part of the work to a minimum, and save enough to many times repay its cost.

"As professional divers charge exorbitant rates for their services, there would be a decided economy as well as a great convenience in purchasing an outfit and doing the diving ourselves."

On my return from Sand Beach, a few days since, I recommended that, in view of the above facts, a diver's suit be purchased. You approved of the plan, and authority has since been received to buy an outfit, which will be put in use as soon as possible.

During the fiscal year 518 vessels entered the harbor; 135 of these passed through the opening, 53 coming in that way and 82 going out.

Mr. Gilbert reports "that the seas or swells entering the opening do not appreciably affect the harbor east of it, and I think the question of its practicability is simply whether it will be used to an extent sufficient to warrant the loss of about 350 feet of pier for securing vessels."

As the necessity for a north entrance becomes more important as the breakwater increases in length, the experience of several years will be necessary to determine this.

There does not seem to exist now among the vessel-men (as far as I have been able to observe) the same prejudice against the opening that there was formerly. More are using it every season, and for the present I would not recommend any change in it.

Annexed is a table showing the number and kind of vessels entering the harbor from April to December, 1876. Also the direction of the wind causing them to seek shelter there.

I am, general, very respectfully, your obedient servant,

A. N. LEE,
Captain of Engineers.

Maj. G. WEITZEL,
Corps of Engineers, U. S. A.

Tabulated record of lake craft taking refuge in the harbor during the season of 1876.

Month.	Totals.	N. W.			N.			N. E.			E.			S. E.			S.			S. W.			W.		
		Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.
April	14	..	2	..	6	1	1	1	..	..	..	..	..	2	1	..	..	..	..	..	..	..	..	..	..
May	46	1	2	4	4	11	2	1	4	1	1	1	..	1	1	..	..	..	..	1	1	..	1	5	1
June	13	2	..	3	..	2	..	..	..	..	..	..	..	1	..	1	1	2	1	..	..	..	..	..	..
July	52	..	..	..	12	3	20	4	5	..	..	..	..	..	..	..	..	..	..	..	..	..	3	2	3
August	28	5	2	12	..	4	..	1	1	..	..	..	..	..	1	..	2	..	..	..	..	..	..	..	..
September	138	8	4	8	8	9	8	16	3	13	1	..	..	9	1	14	..	..	..	..	2	..	5	19	10
October	179	12	6	8	1	2	7	..	..	..	..	..	..	5	8	9	1	4	3	5	11	10	26	27	34
November	44	..	..	..	6	5	6	..	..	..	..	..	..	5	4	3	..	..	..	1	..	..	4	10	..
December	3	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..
Total	...	29	16	35	37	37	44	23	13	14	2	1	..	23	16	27	4	6	4	7	14	10	39	65	48
	517	80			118			50			3			66			14			31			155		

CC 3.

IMPROVEMENT OF AU SABLE RIVER HARBOR, LAKE HURON, MICHIGAN.

In order to ascertain the present condition of this work I ordered my assistant, Capt. A. N. Lee, Corps of Engineers, to inspect it and make a report.

The following is a copy of his report:

UNITED STATES ENGINEER OFFICE,
Detroit, July 11, 1877.

MAJOR: I have the honor to report that, in obedience to your instructions, I have inspected the Au Sable River improvement, and beg leave to submit the following in connection therewith.

I found the south pier in a much worse condition than at the date of my last inspection, October, 1876. I reported then that a large portion of the crib-work had been undermined by the current, and had tilted on the river side to the water's edge. In some places now the river-walls of the cribs are entirely under water, and the damage is gradually extending toward the lake-end of the pier. To repair this would

necessitate the removal of the damaged cribs and ballast for a distance of at least 150 feet, and there is no reason to suppose that the new work, if built in the same manner, would stand any longer than this.

The north pier has settled a little on the river side, but is generally in as good condition as it was last year.

Soundings between the piers show a good depth of water (from 10 to 13 feet) from the angle in the south pier to the heads of the piers. Outside of the piers I was unable to find less than 8¼ feet of water, which leaves the bar in about the same condition it was at the time of Mr. Ulffer's survey in July, 1875. From the angle in the south pier to the upper end of the same the water shoals from 10¾ to 6¼ feet. Above that the river is entirely useless for vessels, there being in some places only 3 feet of water.

This state of affairs has been caused by the gradual encroachment on and changing of the channel by the lumbermen in driving piles, building docks, cutting passages through the river banks for their own convenience in reaching their mills with their logs, in fact using the river in every way as if it were their own private property and not a common highway.

As a general thing the river above the piers, and very often between them, is entirely blocked up with rafts of logs which are allowed to lie there as long as it suits their owners' convenience. As far as the business of the place is affected there is not the slightest need to spend another cent for the improvement of the river or for keeping the present work in repair. Very few vessels enter the river, and these cannot go beyond the end of the south pier. The business is now almost entirely carried on from the mills by tramways directly to the docks. In one case a tramway is built directly across the river.

For the above reasons I would not recommend any further expenditure, either on repairs of the piers or in dredging outside of them.

Very respectfully, your obedient servant,

A. N. LEE,
Captain of Engineers.

Major G. WEITZEL,
Corps of Engineers, U. S. A.

I have only to add to this that, unless I receive instructions to do so, I will not expend another cent on this work. Neither the local nor State authorities have taken any steps to prevent the lawless acts of private owners along the river banks, of which I have complained in several previous reports.

Money statement.

July 1, 1876, amount available	$1,426 62
Amount appropriated by act approved August 14, 1876	1,000 00
	2,426 62
July 1, 1877, amount expended during fiscal year	313 13
July 1, 1877, amount available	2,113 49

C C 4.

IMPROVEMENT OF ALPENA HARBOR, AT MOUTH OF THUNDER BAY RIVER, MICHIGAN.

The survey for the improvement of this harbor, which is situated at the mouth of Thunder Bay River, Michigan, was made last year. A report of the survey, with an estimate of cost, was submitted with my last annual report.

The act approved August 14, 1876, made an appropriation of $4,500 to do the work, but this sum was not available until I received the letter from the office of the Chief of Engineers dated May 1, 1877.

A project for the expenditure of the appropriation was submitted and approved, and bids invited for the work in the usual manner.

These bids will be opened on July 7, 1877, and contract awarded.

The work will be finished and closed during the present season.

No further appropriation will be required.

This work is situated in the Port Huron collection-district. The nearest port of entry is Port Huron, Michigan. The nearest light-house is at the mouth of Thunder Bay River.

The amount of revenue collected during the year was, coin, $146,675.20; currency, $21,870.64.

Money statement.

Amount appropriated by act approved August 14, 1876	$4,500 00
July 1, 1877, amount available	4,500 00

CC 5.

IMPROVEMENT OF THE SAINT CLAIR RIVER, AT THE MOUTH OF BLACK RIVER, MICHIGAN.

The work on this improvement was continued during the fiscal year with the balance of the appropriation of $10,000 made by the act of Congress approved March 3, 1875.

It was stopped on September 30, 1876, by the exhaustion of the appropriation, final payment made to the contractors, and closed.

There are now no less than 15 feet of water below bench-mark for a distance of 1,100 feet from the American shore.

All that there is left of a shoal is located on the edge of the main channel immediately abreast of the isolated railway dock. Its lower extremity is 1,100 feet, and its upper extremity 1,400 feet distant. Through the shallowest of this there has been made a cutting 100 feet wide for a distance of 600 feet from its upper extremity, and then 75 feet wide, to the deep water below.

It would require the dredging of about 4,000 cubic yards to remove this shoal to the same depth as the remainder of the improvement.

There are no less than 13.4 feet of water on any part of this remnant of the shoal, and so small a depth is found only over a space not exceeding 50 square feet.

In order to make a complete thing of this improvement I respectfully recommend that this remnant of the shoal be also dredged to the uniform depth of 15 feet below bench-mark.

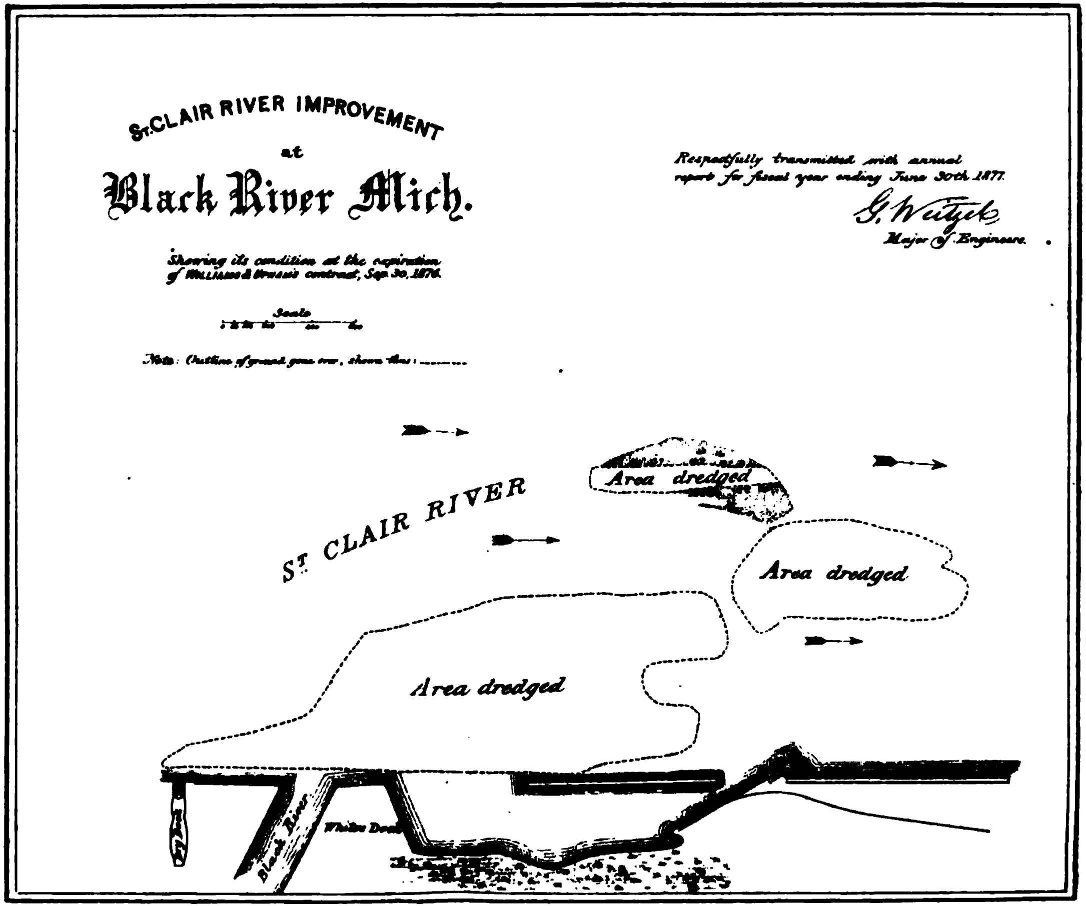
The amount of work to be done being so small the cost per cubic yard will be relatively greater, and I estimate that the sum of $1,500 will be required to do it thoroughly. I respectfully recommend that this sum be appropriated for this purpose for the fiscal year ending June 30, 1879.

No work can be done here during the present season, nor the present fiscal year, ending June 30, 1878, for want of funds.

The original estimate made for this work by Maj. O. M. Poe, in his report dated July 21, 1871, was 168,300 cubic yards of dredging, at 40 cents, $67,320.

The amounts appropriated for it have been as follows, viz:

1872	$15,000
1873	15,000
1874	15,000
1875	10,000
Total	55,000



St. CLAIR RIVER IMPROVEMENT
at
Black River Mich.
Showing its condition at the expiration
Scale
Note: Outline of ground gone over, shown thus: ....
Respectfully transmitted with annual report for fiscal year ending June 30th 1877.
G. Weitzel
Major of Engineers.
St. CLAIR RIVER
Area dredged
Area dredged
Area dredged
Black River

The amount of work done has been 166,570 cubic yards of dredging.

If the work is made complete, as recommended by me, the account will stand 170,570 cubic yards of dredging, at a cost of $56,500.

This shows that Major Poe's estimate was remarkably close in quantities, and, considering the depreciation in the cost of work during the last three years, in cost.

A sketch showing the present condition of the work is attached hereto.

Nearly the whole commerce of the northern and northwestern lakes passes here, and has been benefited by the improvement.

This work is located in the collection-district of Huron, Michigan. The nearest port of entry is Port Huron, and the nearest light-house is at Fort Gratiot, Michigan.

The amount of revenue collected in this district during the year was, coin, $146,675.20; currency, $21,370.64.

Money statement.

July 1, 1876, amount available	$5,390 52
July 1, 1877, amount expended during fiscal year	5,390 52
Amount (estimated) required for completion of existing project	1,500 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	1,500 00

C C 6.

IMPROVEMENT OF DETROIT RIVER, MICHIGAN.

I stated in my last annual report on this work that I had submitted a project for the expenditure of the available balance of the $25,000 appropriated by the act approved June 23, 1874; that it had been approved, and that I would advertise for proposals. This was done and the proposals were opened on August 4, 1876. An abstract of these proposals is hereto annexed.

The lowest bidders, Messrs. Case & Jennings, of Dunkirk, N. Y., were so much lower in their price than any of the others that there was some hesitation in awarding them the contract. But as an examination proved them perfectly responsible there was no alternative.

The following report of my assistant, Capt. A. N. Lee, Corps of Engineers, shows in detail the progress and history of the work during last season and the whole of the fiscal year:

UNITED STATES ENGINEER OFFICE,
Detroit, July 5, 1877.

MAJOR: I have the honor to submit the following report of the improvement of the Detroit River at the Lime-kiln Crossing for the year ending June 30, 1877:

Bids for the work under the appropriation of $25,000 approved June 23, 1874, were opened August 4, 1876, and the contract awarded to Messrs. Case & Jennings at $7.50 per cubic yard. The contractors began work September 25. The point selected for the work is directly in front of the Canada Southern Railroad dock. It is the shoalest spot, and directly in the way of deeply-laden vessels coming down the river, as they have to haul up here to get on the ranges on Bois Blanc Island. The work was carried on from the deck of a raft, and the drilling done entirely by hand. The deck of the raft was perforated at equal distances, and in the holes 3-inch iron pipes inserted. Through these the drills, 2 inches in diameter, were worked. Eight holes (half the number) were worked at once, each drill requiring four men. Each position of the raft was determined by an instrument from shore. During the drilling the raft was raised by means of spuds from the surface of the water, and lowered again before blasting.

The average depth of holes was 4½ feet. At the commencement of the work the contractors used Oriental rifle-power, in charges of 3½ pounds, but after trying this for about three weeks they found it did not answer their purpose, as the rock was not

broken in pieces small enough for the dredge to handle. But 122 cubic yards of rock blasted by powder were taken up by the dredge.

On October 30, nitro-glycerine was substituted for the powder, and used in 3-pound charges. The total number of pounds used was 700. The whole amount of rock removed during the season was 985 cubic yards. In some places, owing to the upheaval of rock that could not be dredged, soundings showed a decrease of about 2½ feet in the depth of water.

To protect shipping in passing these places at night, a red light was kept up at the head of the shoal till the ice formed.

Work was resumed this season on the 20th of April. Many delays were caused at first by the grounding of heavily-laden vessels on the work, and also by breaking the machinery of the dredge. Our red light was also carried away so frequently by small vessels running directly over the work as to cause considerable expense and trouble. After having used the nitro-glycerine on hand from last season's work, the contractors substituted mica-powder. The results proved entirely satisfactory. The mica-powder leaves the blasted rock in much better condition for the dredge. It is about 50 per cent. cheaper, and can be safely handled. The charges used were from 4½ to 5½ pounds, depending on the depth of the hole.

The work was closed on June 19, the appropriation being exhausted. Particular instructions were given the assistant in charge, Mr. Leavitt, that no blasted rock should remain undredged at the time the work stopped, and he reports that every care was taken to remove all such material, so that the work now remains in as good condition as it was possible to leave it with such a small appropriation as we had to work with.

The total amount of rock removed during the year was 2,632 cubic yards.

The contract-price was considered at the time remarkably low, and other bidders expressed the opinion that the contractors would not be able to do the work at their figures. Results have shown, however, the contractors have not only been able to do the work at their prices, but have made a good profit.

In the fall of 1875, the Canadian government expended a small appropriation in the immediate vicinity of our work. From the information I was able to obtain at the time, they bored 50 holes, and took out 120 cubic yards. They used nitro-glycerine in charges of ½ pound, and the work cost them about $60 per cubic yard.

The importance of this work to the commerce of the entire chain of lakes should insure the passage of an appropriation sufficiently large to continue the work economically and rapidly. The blasting already done has had the tendency in places to leave the bottom in a very ragged condition, and in some places has materially decreased the depth of water. A vessel striking one of these sharp edges would be more damaged than by grounding on the smoother surface of the rock before being blasted. Until these shoal places can be gone over and removed, a buoy in the day-time, and a light at night, should be kept up.

It is estimated by prominent vessel-men here that the total tonnage passing the Lime-kiln Crossing annually is 10,000,000 tons, and if vessels could load safely to 15 feet, the gain, with the vessels now in commission, would amount to half a million tons.

Very respectfully, your obedient servant,

A. N. LEE,
Captain of Engineers.

Maj. G. WEITZEL,
Corps of Engineers, U. S. A.

The result obtained by these contractors on this small piece of work, which can hardly even be called a beginning of the improvement, has been perfectly astonishing to me. With but very crude appliances, with a succession of delays and experiments on different explosives, with almost continual interruption, they did the work, and made a fine profit at $7.50 per cubic yard. I never thought of estimating it at less than $25 in any of my official communications. I am now convinced that if Congress will make a single appropriation of $200,000, I can make a channel 20 feet deep and 300 feet wide across this dreaded obstruction. I never estimated it before at less than one million dollars.

As the price at which the contractors undertook the work seemed to me excessively low, I required them to go down to 20 feet depth in their work.

Now, in the points where the excavation stopped when the work was closed for want of funds, there is, of course, an abrupt shoulder in the rock which forms the bottom of the river, and there is more danger of damage to the large vessels than there was before. I have written to

the inspector and engineer of the tenth light-house district to mark the dangerous spot by a buoy for day-time, and a light at night.

All the commerce between Lake Erie and the upper lakes passes this point. The Lime-kiln Crossing has always been a dreaded spot, and one prolific of disaster. Any improvement made here, by making a deeper channel, is a permanent one, and never will need repairing or cause any expense for maintenance.

Captain Lee states that it is estimated by prominent vessel-men that 10,000,000 tons pass this point annually, and if vessels could load safely to 15 feet, (as they could if this improvement were made,) the annual gain to these vessels would be 500,000 tons.

Now, if we only take one-half of these figures as the correct ones, or even one-fourth, it will be seen that at the very lowest rates of freight, say $1 per ton, this improvement would be of vast benefit to the great commerce of the lakes.

In view of these facts, and the undoubted national importance and character of this work, I recommend that the sum of $200,000 be appropriated for its completion by Congress at its next session, and that this appropriation be made immediately available.

In consequence of the low prices at which we can do the work, we require no assistance from Canada, and it need not be delayed by waiting for co-operation from that source.

This work is located in the collection-district of Detroit, Mich.; the nearest port of entry is Detroit, Mich., and the nearest light-house Mamajuda light. The amount of revenue collected in this district during the year was, in coin, $226,548.51; in currency, $31,271.64.

The whole commerce of the great chain of northern and northwestern lakes will be benefited very much by this work.

The only amount appropriated for this work was $25,000 by the act of Congress approved June 23, 1874.

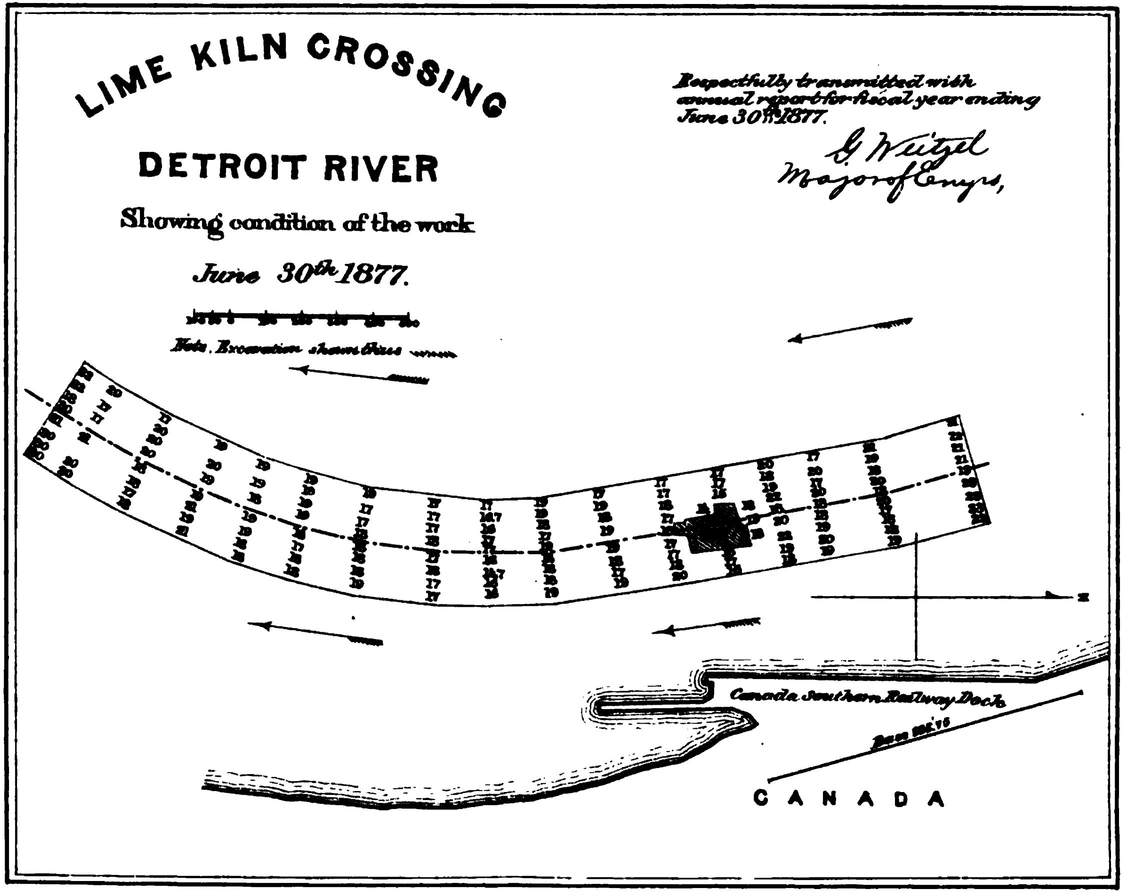
A sketch showing the location at which the work was done, with a few characteristic soundings, is annexed to this report.

Money statement.

July 1, 1876, amount available	$21,446 10
July 1, 1877, amount expended during fiscal year	21,446 10
Amount (estimated) required for completion of existing project	200,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	200,000 00

Abstract of bids for improving Detroit River, under the act of Congress approved June 23, 1874, *opened by Major G. Weitzel, Corps of Engineers, on August* 4, 1876.

Number.	Names of bidders.	Residences.	Removing bowlders, per cubic yard.	Removing solid rock, per cubic yard.
1	Case & Jennings	Dunkirk, N. Y	$6 00	$7 50
2	Charles S. Barker	Sault Ste. Marie, Mich	2 50	20 00
3	Nathaniel Stickney	Detroit, Mich	3 00	19 90
4	Elliot P. Harrington	Detroit, Mich	5 25	19 50
5	Hervey S. Dale	Chicago, Ill	4 25	22 75
6	Edward Moore	Portland, Me	6 00	22 00
7	Wilcox, Stock & Co	Toledo, Ohio	11 40	18 40
8	Martin Quigley	Saint Louis, Mo	25 00	35 00
9	Charles Stange	Detroit, Mich	32 00	35 00


LIME KILN CROSSING
DETROIT RIVER
Showing condition of the work
June 30th 1877.
Respectfully transmitted with annual report for fiscal year ending June 30th 1877.
G. Weitzel
Major of Engrs,
Canada Southern Railway Dock
CANADA

APPENDIX D D.

ANNUAL REPORT OF MAJOR FRANKLIN HARWOOD, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Detroit, Mich., July 14, 1877.

GENERAL: I have the honor to transmit herewith my annual report for the works of river and harbor improvement placed under my charge by the operation of Special Order No. 44, dated Headquarters of the Army, February 27, 1877, and of the charge of which I relieved Major Godfrey Weitzel on March 19, 1877.

I am, general, very respectfully, your obedient servant,

F. HARWOOD,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

D D 1.

IMPROVEMENT OF SAINT CLAIR FLATS SHIP-CANAL, MICHIGAN.

Beyond a few minor repairs done by the custodian, by aid of a few laborers employed from time to time as needed, no repairs have been made upon this work during the past fiscal year.

The change of position in the plank protection, noted in the last annual report, has proved effectual in protecting the reverse of the canal banks, and is a much better arrangement than that heretofore adopted. Several washers and sinks at various points in both dikes began to claim attention in the autumn of 1876, but owing to the high water and the difficulty of obtaining and placing at that time the requisite repair material, any effort to repair these damages was postponed until the opening of navigation in 1877. In a very unexpected manner in the early spring of 1877 these damages were suddenly and alarmingly increased. The upward-bound fleet of vessels, released from winter quarters by the opening of navigation in the lower lakes, were unexpectedly met at the canal by an extraordinary and continuous flow of running ice pouring down the Saint Clair River day after day from Lake Huron, rendering their further progress impossible for the time, and their return across Lake Saint Clair extremely hazardous. As a natural consequence, as long as this state of affairs lasted, during the early part of May, the canal was taken possession of as a harbor of refuge, and as it never was intended for such use, and consequently had no facilities for vessels to make fast to the banks, both dikes were badly damaged by tugs and propellers, injuring the willow growth or plank revetment, or working their wheels violently in close proximity to the timber revetment, thereby sucking out through the meager sheath-piling the loose sand-filling to such an ex-

tent as to occasion numerous and extensive caves and washes, amounting in the aggregate to about 4,000 cubic yards in volume. The entire damage thus caused will cost in repair probably from $2,000 to $4,000, depending upon the rates at which I shall be able to obtain the repair material, for which I am now advertising, bids to be opened on the 11th of this month, the repairs to be effected in the course of the summer. As the material I have selected is to be had in plenty and near at hand, I hope to reduce the cost of repair to the minimum, possibly between $1,000 and $2,000.

Although a greater part of this damage, and that which will cost the most to repair, was done by tugs in an effort for self-preservation of themselves and vessels in tow, there still remains the fact that they deliberately elected to work damage to the United States rather than run a risk of the safety of their own property. It is also a fact that the canal was not and is not intended as a harbor of refuge, but simply as a means of convenient transit over the Saint Clair Flats, and it is only by its misuse in this instance that this damage has been worked. At the instance, therefore, of the Chief of Engineers, and in vindication of the law enacted in section 3, act of Congress approved August 14, 1876, I have selected a few test cases in which the United States is undoubtedly able to prove the facts of damage deliberately inflicted, which cases I have placed in the hands of United States attorney for the eastern district of Michigan, that officer having, at the request of the Secretary of War, been directed by the Attorney-General—

To take prompt measures to enforce in reference to the damages upon Saint Clair Flats Canal the provisions of the third section of the act of August 14, 1876, punishing by fine those guilty of injuring the piers, breakwaters, or other works of the United States in the improvement of rivers and harbors.

While, as I have said, in each of these cases the United States will offer undoubted testimony as to the facts, there is still a doubt as to whether, under the vague terms "willfully and unlawfully," a judgment can be obtained in any or all of the cases.

I therefore respectfully recommend that Congress be requested at its next session to revise the law by substituting for the words "willfully and unlawfully" the words "from any cause other than unavoidable accident," or the common-law term "knowingly," under either of which phrases it appears to me offenders can readily be convicted when the facts are proven. I am advised that as the law reads now, such a result is by no means certain.

The repairs of the damages above referred to will constitute the operations for the coming year, unless others should unfortunately be hereafter inflicted.

As the balance on hand of the existing appropriation for this work will, in all probability, be nearly exhausted in the expenses growing out of this extraordinary damage to the canal banks, and as it would seem only a measure of prudence to keep on hand a sufficient fund to meet any emergency which may arise whereby through sudden and extensive damage this important thoroughfare may be closed to navigation for want of funds to restore and keep it in navigable condition, I respectfully recommend an appropriation of $5,000 at the next session of Congress for the repair and preservation of this work.

It is located in the collection-district of Detroit, Mich. The nearest port of entry is Detroit, Mich., but this has no especial bearing on the commercial importance of the work, as the whole commerce of the great lakes is greatly benefited by its existence, and the revenue of every custom-house on the lakes incidentally increased by the facilities it offers as an important cut-off in the great thoroughfare from Lake Erie to Lake Huron.

For revenue statistics, therefore, see general reports of lake custom-houses.

There are two light-houses on the canal banks.

Money statement.

July 1, 1876, amount available	$11,208 14
July 1, 1877, amount expended during fiscal year	5,359 16
July 1, 1877, amount available	5,848 98
Amount (estimated) required for preservation of existing work	5,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	5,000 00

D D 2.

IMPROVEMENT OF SAGINAW RIVER, MICHIGAN.

Upon taking charge of this work, on March 19, 1877, I found the operations for the coming working season fully provided for according to the approved project already adopted.

The appropriation of $11,000 made by act of Congress approved August 14, 1876, not being available in time to undertake any work during the working season of that year, no action for continuing this work of improvement was taken until early in 1877, when proposals were invited for adding about 1,000 feet to the revetment opposite the Carrollton Bar, which has been in progress for several years. Bids were opened on March 10, 1877, and subsequently, upon my recommendation, the award for the supply of labor and material for 1,000 feet additional revetment was made to Hervey S. Dale, of Chicago, Ill., the lowest responsible bidder, with whom contract was afterward made. Work was begun on the 31st of May, and at the close of the fiscal year 325 linear feet of revetment in an incomplete state had been added to the work of last year.

The slab filling of last year's work, which had settled badly in several places, was also overhauled and renewed.

Shortly after taking charge of the work I ascertained, by personal inspection, that the revetment—the result of several years' expenditure of money and labor—was not effecting the improvement for which it was designed to the extent anticipated, owing to the flow of the river current under a pier heretofore known as Wickes' dock, but now the property of Mr. Jesse Hoyt, of New York.

This current scouring behind the revetment detracted from its full effect upon the Carrollton Bar, designed to be improved by the abrading action of the current confined within suitable limits by the revetment and the river-bank on the Carrollton side. Much of this action was lost for lack of confining the current entirely in the proposed channel. To effect this, the necessity for which had already been anticipated by my predecessor, I submitted a project for running a bulkhead from the up-stream end of the United States revetment across to the made land on Hoyt's mill-site, thereby cutting off the current behind the revetment and confining it to the main channel designed to be improved. This project being approved, Mr. Hoyt concurring, and the work being also within the provisions of the contract, the general plan of construction of the revetment being followed in the bulkhead, arrangements have been made, and this bulkhead will be constructed without delay

Accordingly, at the close of the working season of 1877 this bulkhead will be completed, and, besides this, as many linear feet of revetment as the appropriation will afford will also be added to the down-stream end of last year's work, securing at the same time by dredging a good navigable channel of 10 feet in depth abreast of the revetment to its full extent.

Carrying out the project in this manner, the river-revetment will probably be extended about 500 feet, but all will be subordinated to the more important measure of cutting off the river current behind the revetment by means of the bulkhead at Hoyt's mill-site. The appropriation will probably be expended under the contract early in the autumn of 1877.

Further improvement will depend upon further appropriation. I am happy to say that the effect of the improvement made in successive yearly stages is already perceptible as regards Carrollton Bar, heretofore one of the major obstacles to the navigation of the river in approaching East Saginaw.

There have been no complaints this year brought to my attention of any difficulty in navigating the channel with vessels of the draught designed to be accommodated.

The permanent improvement of the channel opposite Carrollton Bar will be nearly completed as a result of this year's operations. It will only require a slight additional expenditure to connect the incomplete revetment with the main-land opposite the down-stream end of the bar, and when this is done, and the channel properly dredged abreast of it, this portion of the improvement will be completed. As regards the lower bars at Zilwaukee and New York works, it does not appear, from all the information I have been able to gather, that their condition has materially changed during the year in any way under the influence of the improvement progressing above at the Carrollton Bar; neither do I consider it expedient to undertake any work at these localities until the up-stream work is thoroughly finished; and, as I have had charge of this improvement for too short a period to be able to form a definite judgment as to what will be required for the improvement of these bars, in making estimates for further improvement I adopt the figures of my predecessor, as set forth in his last annual report, remarking, however, that where so many unknown quantities enter into the problem of the improvement of a river of this character, through so many reaches, and comprising bars situated miles apart, estimate must necessarily verge closely on conjecture, excepting in the case of work which can be actually projected in detail for some definite locality. I further remark, however, that all the funds for which I estimate can be profitably expended within a single working season, and expended much more profitably in this way than if afforded by driblets year after year in such a manner that the one year's work is in a great measure lost in waiting for the next.

The importance of the improvement of Saginaw River, in a commercial point of view, has been fully set forth in preceding annual reports. In addition to the statistics herewith appended, as furnished me by the deputy collector of customs, I also beg leave to add the official statement of the Michigan Salt Association, that they have shipped from all points of the river above Carrollton Bar during the fiscal year ending June 30, 1877, 414,974 barrels of salt, which demonstrates only the magnitude of one interest affected by the river improvement, the lumber-trade being probably of still greater importance.

This work is located in the Huron collection-district, Michigan. The nearest light house is at the mouth of the river. The nearest port of entry is Port Huron, Mich.

The original estimate for this work was $56,000, the whole amount of which has been appropriated, as follows:

1874	$15,000 00
1875	30,000 00
1876	11,000 00
Total	56,000 00

Of which amount $45,597.99 was expended up to the close of the fiscal year.

The reason for the estimate presented in this report for an additional appropriation beyond the amount originally estimated is given in full in the last annual report.

Money statement.

July 1, 1876, amount available	$1,184 13
Amount appropriated by act approved August 14, 1876	11,000 00
	12,184 13
July 1, 1877, amount expended during fiscal year	1,782 12
July 1, 1877, amount available	10,402 01
Amount (estimated) required for completion of existing project	50,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	50,000 00

COMMERCIAL STATISTICS.

EAST SAGINAW, *July* 7, 1877.

DEAR SIR: In addition to the inclosed statement there have been sundry fees collected to the amount of $196.04.

In giving you these figures, I wish to say that I do not deem this port fairly dealt with, as many vessels enter here on clearances from lower ports, going either to Chicago, Milwaukee, or other northwestern ports, and who take either full or part cargoes from here, for which we get no credit; and in addition it is an almost daily occurrence that vessels take whole or part cargoes here and above, and clear at Bay City, which is an evidence of cargoes being shipped on through-clearances, as shown by the custom-house reports from Chicago, Port Huron, Buffalo, Erie, and other lower lake ports that get credit for lumber and salt, which points manufacture neither lumber nor salt to a very great extent, unless it is Port Huron.

Yours, very truly,

A. FERGUSON,
Deputy Collector.

B. H. MUEHLE,
United States Inspector.

Summary statement of vessels in the coasting trade that have entered and cleared from the port of East Saginaw, and also the amount of fees collected, for the fiscal year ending June 30, 1877.

Months.	Entered.	Tonnage.	Cleared.	Tonnage.	Fees.	Gold.
1876.						
July	58	17,271	58	17,287	$69 60	....
August	74	21,233	69	19,557	84 80	....
September	85	24,865	85	24,678	126 70	....
October	97	31,770	90	26,701	111 30	$90 95
November	55	17,002	50	15,035	64 10	172 40
1877.						
May	78	22,844	79	22,987	194 50	....
June	135	41,331	104	30,781	140 75	....
Total	582	176,316	535	157,026	791 75	263 35

East Saginaw, July 7, 1877.

A. FERGUSON,
Deputy Collector.

B. H. MUEHLE,
United States Inspector.

Abstract of proposals for continuing the improvement of Saginaw River, Michigan, opened March 10, 1877.

Number of bid.	Names of bidders.	Residences.	Pine timber, per thousand feet.	Piles and driving, per linear foot.	Bolts, &c., per pound.	Slabs in place.	Stone in place.	Dredging, per cubic yard.	Total.
				Cents.	*Cents.*			*Cents.*	
1	Hemmingway and Hayes.	Painesville, Ohio	$20 00	12	4	$1 35	$7 00	30	$8,838 41
2	Courtland D. Merry.	Vernon, Ohio.............	20 00	14	$3\frac{3}{4}$	1 40	7 75	40	9,634 57
3	Edwin H. French.	Fulton, Oswego County, New York.	20 00	15	4	1 50	9 00	35	10,103 75
4	Hervey S. Dale ...	Chicago, Ill...............	18 00	14	$4\frac{1}{2}$	1 10	7 00	35	8,627 07
5	Charles S. Barker.	Sault Saint Marie, Michigan.	20 00	15	4	1 25	8 00	27	9,156 00
6	Farris & Garfield	Painesville, Ohio	28 00	12	$3\frac{1}{2}$	1 65	8 00	40	10,523 41

Abstract of contract.

Contract with Hervey S. Dale, of Chicago, for furnishing material and labor for extension of pier revetment and dredging, dated April 21, 1877, to expire September 1, 1877.

Abstract of contract for each class of material and labor.

1. Pine timber framed and put in place, per M feet, board-measure........... $18 00
2. Oak or Norway pine piles and driving, per linear foot.................... 14
3. Drift-bolts, screw-bolts, and washers, in place, per pound................. $04\frac{1}{2}$
4. Slabs in place, per cord.. 1 10
5. Stone in place, per cord.. 7 00
6. Dredging, per cubic yard... 35

DD 3.

IMPROVEMENT OF CHEBOYGAN HARBOR, MICHIGAN.

For lack of available appropriation nothing has been done during the fiscal year in continuing the work of improvement of this harbor.

By act of Congress approved August 14, 1876, $10,000 was appropriated for this improvement, but was withheld from application by direction of the President of the United States until May 7, 1877, when I received notification that the President had decided to release the appropriation, and I was directed to submit a project for continuing the improvement. This I decided to do, first, by finishing an incomplete dredge-cut, thereby getting a uniform width of channel from harbor to lake; second, in cutting off a point of land in the Cheboygan River, to give a width of 200 feet channel-way at the harbor end of the approach from Lake Huron; third, by expending the balance of appropriation, if any, in improving by widening the lakeward end of the channel of entrance.

This project being approved by the Chief of Engineers, proposals for the hire of the necessary dredging-equipment were advertised for, and bids will be opened on the 14th of the present month. It is expected to exhaust the appropriation in the manner above projected in the course of the present working-season.

From an examination of the channel already dredged, and which has remained untouched for over a year, it does not appear that the slight

annual silting in effects enough shoaling to warrant the United States going to the expense of building a pier of protection to the dredged channel. The channel once completed, slight annual dredging may be required to keep it in good navigable condition, but from present appearances and past experience, as recorded in the several annual reports while the improvement has been going on, it is probable that such dredging as may be required will be entirely within the means of the town authorities to provide for, assisted, if necessary, by such vessel-interests as may be most benefited by the improvement. Should this view of the case prove fallacious, a point which can only be determined by awaiting the developments of time, of course it may become necessary to estimate for further appropriations either for annual dredging or for the construction of a pier of protection, as may be shown to be most economical and effectual in maintaining the channel in good navigable condition. In the light of present information, however, I only estimate for the completion of the channel by dredging to its full width of 200 feet, with 13 feet depth of water at low stage. This is all that commerce demands at present. A beacon-pier at the lake end of the channel would certainly be desirable, but hardly comes within the province of the harbor improvement, being rather the affair of the Light-House Board. I, therefore, confine myself to an estimate for completion of the harbor by dredging, at a total expense of $20,000, all of which I respectfully recommend to be appropriated at the next session of Congress, in order that the channel may be finished, as it readily can be, in the working-season, and the extra expense incidental to breaking off and resuming work thereby avoided.

The national importance of this harbor has been fully set forth in the last annual report.

The original estimate of the cost of this work is $395,000, which was made by Maj. F. U. Farquhar, Corps of Engineers, in 1871.

The amounts that have thus far been appropriated for this work are as follows:

1871	$10,000	1875	$15,000
1872	15,000	1876	10,000
1873	15,000		
1874	15,000	Total	80,000

Seventy thousand and seventy-nine dollars and twenty-three cents of which has been expended upon the work up to the close of the fiscal year, leaving a balance of $9,920.77 to be expended during the present working-season.

This work is located in the Superior collection district, Michigan. The nearest port of entry is Marquette, Mich. The nearest light-house is the Cheboygan light. Number of clearances during the fiscal year, 513. Total tonnage of vessels cleared 195,247. Amount of revenue collected at this port during the fiscal year, $1,413.15.

Money statement.

July 1, 1876, amount available	$262 44
Amount appropriated by act approved August 14, 1876	10,000 00
	10,262 44
July 1, 1877, amount expended during fiscal year	341 67
July 1, 1877, amount available	9,920 77
Amount (estimated) required for completion of existing project	20,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	20,000 00

APPENDIX E E.

ANNUAL REPORT OF MAJOR N. MICHLER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Toledo, Ohio, July 14, 1877.

GENERAL: I have the honor to transmit herewith the annual reports upon the various works of harbor improvement under my charge for the fiscal year ending June 30, 1877.

Very respectfully, your obedient servant,

N. MICHLER,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S A.

E E 1.

IMPROVEMENT OF MONROE HARBOR, MICHIGAN.

The plan adopted for the improvement of this harbor consisted, in the first place, in opening a canal, known as the Monroe City Canal, for the purpose of straightening and shortening the course of the Raisin River at one of its elbows; and, in the second place, by connecting the bed of the river from a point 1½ miles above its mouth, and where the Little Sandy Creek empties into it, with deep water in Lake Erie by a direct channel or cut, the latter designated as the United States Ship Canal. Dimensions of the two canals: Monroe City—length, 1,200 feet; width, 100 feet; depth, 11 feet; United States—length, 4,000 feet; width, 100 feet; depth, 11 feet.

The small appropriations have been applied in the following manner: In digging out and subsequent dredging of the cuts, by protecting their sides with revetment of sheet-piling; in the construction of piers and pier-heads from the shore out into the lake; and, during the last few years, in renewing the revetments of two canals, wherever destroyed, together with repairing and strengthening the outer piers.

The appropriation for the fiscal year just closed, amounting to $5,000, is now being applied to such repairs on the piers as have become necessary through damage incurred by heavy storms and the crushing of ice, and in the renewal of the revetments; it is expected to complete about 2,000 feet of finished work with that amount. As authority to expend the appropriation was not received until the first part of May, and as some little time was consumed in preparing and awaiting the approval of the project for its expenditure, but little work was accomplished during the fiscal year further than the procuring of the necessary materials. The following is the bill of material furnished and put in place:

67 piles driven in place and 1,087 linear feet of revetment.
5,000 feet, board-measure, oak-timber wale and binder pieces, framed and put in place.
481 pounds of iron, nuts and screws, and washer-bolts.

The work is being executed by the purchase of the material in open market and by day-labor, and will be partially finished, as far as the funds on hand will admit, by the latter part of September.

There will remain to be completed, after the present appropriation is exhausted, about 1,500 feet of renewed and extended revetment. The north and south piers will also have to be repaired at times, owing to frequent damage caused by storms. The canal between the side revetment, as well as the bar or shoal in the channel outside of the entrance or pier-heads, will have to be kept dredged to the proper depth. The different works above enumerated will render the United States Canal complete in all its parts, and it is likely to remain in good condition for several years. No full estimate for its entire and permanent completion can be made. It will always be subject, in a more or less degree, to damage by the destruction caused by rottenness of the timbers, from general exposure to the weather, and particularly from the effect of ice and storms. The estimated cost of the present completion of the improvement is $10,000.

The following table supplies the amount appropriated in each year for this work of harbor improvement up to and including the fiscal year ending June 30, 1877:

1835	$30,000 00	1866	$31,015 27
1836	15,000 00	1872	10,000 00
1837	30,000 00	1873	15,000 00
1838	15,000 00	1874	10,000 00
1844	20,000 00	1875	10,000 00
1852	14,000 00	1876	5,000 00
Sum total			205,015 27

The amount of commerce and navigation to be benefited by the completion of this particular work, as will be seen by an examination of the entrances and clearances for the last several years, is not very large; the harbor is not fit for a harbor of refuge for vessels engaged in the commerce of the lakes. There is a light-house on the north pier-head at the outer extremity and entrance to the United States Canal. The light is a fixed white one of the fourth order. The nearest defensive work is Fort Wayne, near Detroit, 30 miles distant.

Monroe Harbor is in the collection-district of Detroit, Mich. Amount of revenue collected during the fiscal year ending June 30, 1877, $30 coin. Entrances and clearances during the fiscal year ending June 30, 1877: Number of vessels, 80; tonnage of the same, 7,120 tons.

Money statement.

July 1, 1876, amount available	$40 54
Amount appropriated by act approved August 14, 1876	5,000 00
	5,040 54
July 1, 1877, amount expended during fiscal year	548 10
July 1, 1877, amount available	4,492 44
Amount (estimated) required for completion of existing project	10,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	10,000 00

E E 2.

IMPROVEMENT OF TOLEDO HARBOR, OHIO.

The original plan for the improvement of this harbor consisted in widening and deepening the outer and inner branches of the southwest channel through Maumee Bay to a width of 120 feet, with a depth of 14 feet at a low stage of water. The work was commenced in 1866,

and was annually prosecuted by contract, according to the specifications then adopted, until the close of the working-season of 1872. In compliance with the request contained in a communication of December 23, 1872, from a committee of the Chamber of Commerce of Toledo, Ohio, which was referred to the Chief of Engineers, the subject of the improvement and preservation of the harbor was submitted to a Board of Engineers, with instructions to report a plan for accomplishing the objects named, one "affording an entrance-channel of not less than 15 feet depth at the lowest stage of water, and of such width and dimensions as the nature and extent of the commerce of that harbor made desirable." The report of the Board is to be found published among the congressional documents of the Forty-second Congress, third session, House of Representatives, Ex. Doc. No. 92. Reference to this report is respectfully requested, as it is fully descriptive of Maumee River and Bay, and states the essential requirements to fulfill the desired needs of the problem under consideration.

In submitting the report the Chief of Engineers briefly recapitulated the three plans of improvement as follows:

The first (plan) being a project for a straight cut through North Cape Point, the estimated cost of which is $1,858,500.

This plan starts from the inner and middle ranges of the natural channel, and precludes the necessity of also closing the present outlet into the bay of Ten-Mile Run—called in the report Ottawa River—by a dam, and by making a new one direct into the lake by a cut through the North Cape. The length of this cut from Presque Isle Point, mouth of Maumee River, to deep water of Lake Erie would be 7.3 miles, or 1.1 shorter than the present or natural channel.

The second plan, which is a modification of the preceding, proposes to extend the river *through the bay* and North Cape to Lake Erie, confining the river-water in a new channel of about the same dimensions as its natural bed. The estimated cost of this project is $3,074,500.

This plan the Board considers the most complete solution of the problem before it, the result of which can be predicted with the most certainty.

This would be simply the extension of the banks by the construction of two lines of pier revetments for the protection of both sides of the proposed new channel from the mouth direct to Lake Erie; and as the Board remarks, it must not be understood that it is a part of this project to dredge a through-cut 900 feet wide, "because there is a possibility that the river-currents will of themselves dredge out this channel to the same depth as the natural channel above," the process being similar to that now taking place at the mouth of the Mississippi.

The third plan is to improve the existing natural channel through Maumee Bay, the estimated cost of which is $450,000.

This plan the Board recommended for adoption for the several reasons stated in the report. The principal one, and a very important one, is that it is the least expensive, and that the estimated cost of either of the other plans would exceed any probable appropriation that Congress is likely to make for this harbor until its importance is more clearly demonstrated.

In the "act making appropriations for the repair, preservation, and completion of certain public works" of river and harbor improvement, approved June 23, 1866, and to which the attention of the officer in charge has been invited by the Chief of Engineers, the question is propounded, "As far as practicable, what amount of commerce and navigation would be benefited by the completion of each particular work?" The most

reliable and instructive answer to this question, as regards this harbor, can be found in an elaborate and carefully-prepared paper entitled "The Eighteenth Annual Report of the Trade and Commerce of the city of Toledo, T. Wales, secretary." The statistics therein furnished will convey in a well-defined manner the importance of the trade of Toledo, and the shipments, both foreign and domestic, of flour and grain and miscellaneous articles of produce. The following tables form but a brief synopsis of the statistics furnished by the authority above mentioned:

Statement of shipments of flour and grain by lake from the port of Toledo during the season of navigation in 1876.

RECAPITULATION.

Whither.	Wheat.	Corn.	Oats.
	Bushels.	*Bushels.*	*Bushels.*
To American ports	3,513,254	2,878,653	165,219
To Canadian ports	217,525	1,588,722	531,091
Total	3,730,779	4,467,375	696,310

Total shipments of flour ... barrels	24,066
Total shipments of grain ... bushels	8,894,464
Grand total flour to wheat ... bushels	9,014,794

Statement of receipts of miscellaneous articles of produce at Toledo via the Canada Southern Railway during the year ending December 31, 1876.

Months.	Coal.	Iron.	Tobacco.	Wood.	Sugar.	Apples.	Salt.	Ice.	Lath.	Shingles.	Staves.	Lumber.	Sundries.
	Tons.	*Lbs.*	*Hhds.*	*Cords.*	*Lbs.*	*Bbls.*	*Bbls.*	*Tons.*	*No.*	*No.*	*No.*	*Feet.*	*Lbs.*
January	120	22,000	....	7	....	....	....	....	....	60,000	....	232,000	121,120
February	12	20,000	....	35	....	150	1,625	....	....	720,000	....	210,000	832,520
March	205	21,200	....	14	....	250	....	44	100,000	1,320,000	60,000	462,000	226,042
April	....	23,200	10	7	....	....	....	....	....	1,380,000	....	392,000	142,098
May	120	138,090	....	28	....	....	....	....	180,000	2,240,000	....	608,000	402,800
June	....	44,400	....	....	....	....	....	....	480,000	1,760,000	....	675,000	429,000
July	....	....	....	14	....	....	....	....	....	....	....	64,000	120,000
August	....	....	....	....	....	....	....	....	....	....	....	16,000	....
September	....	....	....	28	20,000	....	....	....	....	....	....	32,000	....
October	12	580,000	....	14	....	....	....	....	....	....	....	184,000	....
November	....	....	....	21	....	....	....	....	....	....	....	88,000	....
December	....	20,000	....	28	....	....	....	....	....	....	6,000	40,000	....
Total	529	868,890	10	196	20,000	400	1,625	44	760,000	7,540,000	66,000	3,133,000	2,273,580

Statement of the receipts of produce at Toledo via the Miami and Erie Canal during the season of 1876.

Months.	Flour.	Wheat.	Corn.	Oats.	Rye.	Barley.	Feed.	Apples.	Plaster.	Potatoes.	Wood.	Timber.	Hoops.	Staves.	Lumber.	Sundries.
	Bbls.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Tons.*	*Bbls.*	*Bbls.*	*Bush.*	*Cords.*	*Cu. ft.*	*No.*	*No.*	*Feet.*	*Lbs.*
January	....	1,307	1,590	....	....	....	....	....	....	....	....	....	....	....	....	....
March	237	6,613	7,626	2,300	....	....	23	....	....	....	....	....	....	....	....	....
April	751	4,418	36,923	5,650	....	....	19	....	....	....	85	42,056	25,000	20,000	68,490	5,779
May	975	15,636	13,874	5,972	632	....	57	....	....	....	231	....	....	10,000	142,900	56,134
June	1,112	25,341	32,236	20,837	....	....	69	....	100	....	....	20,835	148,000	18,000	95,321	22,460
July	2,216	7,130	7,382	10,132	....	....	79	....	....	....	108	75,598	....	28,208	98,404	12,535
August	4,512	14,772	300	12,255	....	143	309	....	....	....	222	55,260	....	127,310	137,536	8,162
September	4,536	13,104	2,600	14,905	....	1,200	100	....	....	....	413	19,521	....	79,200	94,735	20,250
October	7,561	14,008	6,474	13,315	2,000	....	281	....	....	645	701	71,257	100,000	146,600	148,495	35,125
November	2,607	10,360	5,593	....	380	205	136	47	....	612	230	16,450	....	5,000	96,400	27,340
Total	24,507	112,709	114,598	85,366	3,012	1,608	1,073	47	100	1,257	1,990	300,977	273,000	434,318	882,281	187,785

Statement of the receipts of miscellaneous products by lake at the port of Toledo during the season of 1876.

Articles.		April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Lumber	feet	1, 255, 000	21, 173, 998	15, 961, 309	17, 818, 779	11, 395, 912	9, 719, 133	13, 045, 348	21, 387, 740	653, 306	112, 410, 525
Shingles	number	....	2, 868, 000	1, 378, 000	9, 138, 000	1, 768, 000	3, 367, 000	2, 483, 000	1, 620, 000	....	22, 622, 000
Lath	do	316, 000	1, 085, 950	1, 717, 500	1, 386, 850	459, 900	1, 452, 000	2, 309, 000	2, 638, 000	....	11, 365, 200
Barley	bushels	13, 733	....	....	....	....	....	57, 629	18, 460	18, 056	107, 878
Salt, Saginaw	barrels	10, 425	21, 916	12, 100	12, 007	11, 216	10, 426	28, 747	44, 305	2, 000	153, 142
Salt, Onondaga	do	1, 000	5, 124	1, 300	1, 400	....	6, 800	10, 660	9, 093	....	35, 377
Ice	tons	1, 210	7, 245	1, 068	280	12	100	607	....	....	10, 522
Stone	cords	393	399	100	54	109	401	183	158	....	1, 797
Sand	barrels	382	213	308	....	....	....	110	143	....	1, 056
Cedar posts	number	....	8, 210	1, 220	900	....	6, 000	1, 200	....	....	17, 530
Plaster	barrels	....	2, 690	2, 010	1, 670	300	1, 830	1, 000	5, 250	....	14, 750
Wood	cords	....	20	70	55	60	74	35	30	....	344
Beans	barrels	....	40	....	....	....	....	....	....	....	40
Fish	packages	....	108	....	150	156	....	517	260	....	1, 191
Wheat	bushels	....	24, 500	....	....	....	....	....	....	....	24, 500
Coal	tons	....	500	3, 938	5, 595	2, 473	2, 088	6, 696	7, 456	1, 861	30, 607
Corn	bushels	....	3, 000	....	....	....	....	....	....	....	3, 000
Iron-ore	tons	....	585	6, 455	....	1, 646	1, 111	503	2, 365	....	12, 665
Wine	barrels	....	....	....	....	....	100	30	....	....	130
Grapes	packages	....	....	....	....	....	....	1, 618	650	....	2, 268
Grapes	tons	....	....	....	....	....	....	30	100	....	130
Sugar	barrels	....	....	1, 887	....	292	....	729	....	....	2, 908
Brimstone	tons	....	....	310	....	....	....	....	....	....	310
Oats	bushels	....	....	....	100	....	....	....	....	....	100
Staves	number	....	....	....	....	6, 000	....	....	....	....	6, 000
Timber	feet	....	....	....	....	....	....	800, 000	....	....	800, 000

Statement showing the shipments of miscellaneous products by lake from the port of Toledo during the season of 1876.

Articles.	Quantity.	Articles.	Quantity.
Oak timber....cub. ft	648,500	Oil....bbls	55
Staves....No.	1,021,716	Fish....pkgs.	2,950
Ash lumber....feet	107,000	Grass-seed....bags	74
Black-walnut lumber....do..	2,040,336	Mill-feed....tons.	48
Tobacco....hhds.	1,071	Coal....do..	536
Pig-iron....tons.	2,810	Hay....do..	20
Potatoes....bbls.	200		

The foregoing interesting statement shows the amount of lake commerce benefited during the year 1876, and there is every reason to believe that it will be largely increased.

Since the commencement of the present year a new railroad, the Columbus and Toledo, has been completed, and has its terminus on the river. The company has been engaged lately in the construction of an immense dock on the river-front, preparatory to the shipment by the lake of large quantities of grain, coal, lumber, and other products from the interior of the State, and from further south. In addition to the Columbus and Toledo Railway, the following are the several sources of supply and shipment: The Detroit and Toledo; Canada Southern; Toledo and Chicago Air-Line; Wabash; Lake Shore and Michigan Southern; Dayton and Michigan; Toledo, Tiffin and Eastern, (Pennsylvania Central;) Atlantic and Lake Erie Railways; the Miami and Erie Canal; the lakes; and the home manufactures.

The plan as finally adopted consisted in dredging out the natural or existing channel to a width of 250 feet at the top, and 200 at the bottom, with a depth of 15 at an average stage of low water; also that the sweeps at the angles or elbows, of which there are four, shall be so rounded that vessels will be able to pass from one reach to another without difficulty. The work has been prosecuted by contract. During the season of 1876 operations were not undertaken, as the balance remaining on hand was not sufficient to justify it, and the authority to spend a portion of the succeeding appropriation was received too late to accomplish anything. The dredging was resumed on the 30th of April of this year, a contract dated April 18 having been entered into with William Richardson, of Buffalo, N. Y.; the amount to be expended not to exceed the first allotment of $22,500 from the appropriation of $60,000 approved August 14, 1876, the use of which had been authorized September 14, 1876. Two dredges were placed at work on the north or outer reach of the channel, but subsequently one was removed to the southwest reach. On the 18th of June a second contract, the amount to be limited to the unallotted balance, $37,500, was made with Orville J. Jennings, of Dunkirk, N. Y., to place three additional dredges, with the necessary tugs, dumping-scows, and other appliances, on the work. Two were accordingly placed in position on the 25th of the same month, and immediately commenced operations. The contractor was authorized by the Secretary of War to extend the time until the 10th of July for the third to arrive in the harbor; and it may be here stated that it arrived promptly on the designated day. The three last dredges were also placed at work on the outer or north reach at the entrance of the channel, opposite Turtle Island. During the months of May and June the dredges have cut and raised 44,541 cubic yards of sand and clay, which was towed out and dumped into deep water of the lake. By the terms of the two contracts, there will be removed from the channel nearly 380,000 cubic yards

of material. No exact estimate can be made as to the quantity which will require removal in order to complete the channel to its full dimensions during the fiscal year ending June 30, 1879, as the filling in of the dredged cut is being effected to a greater or less extent through the winter and spring months, and during the occurrence of severe gales on the lake. The filling or washing in can only be prevented by the protection of the two sides of the channel by a facing of some material sufficiently durable and laid in accordance with any one of the plans usually adopted for the purpose, such as revetment constructed of sheet-piling through the bay, and piers of crib-work extending out into the lake. When this is done the improvement can be more readily considered as entire and permanent. It is estimated that an appropriation of $110,000 will be required to execute the plan as adopted, and the entire amount can be profitably expended during the year. Small annual expenditures will have to be made after the completion of the first thorough cut throughout its entire length, in order to dredge such material as may be subsequently washed in by the waters of the bay.

The following is a statement of the amounts and date of all former appropriations for this work of improvement, including the year ending June 30, 1877:

1866	$20,000 00	1873	$100,000 00
1867	20,000 00	1874	75,000 00
1869	29,700 00	1875	75,000 00
1870	50,000 00	1876	60,000 00
1871	50,000 00		
1872	15,000 00	Total	494,700 00

Abstract of bids received and opened at 12 o'clock noon of the 4th of April, for improving harbor at Toledo, Ohio.

Name of bidder.	Residence.	Price per cubic yard.
		Cents.
Edwin H. French	Fulton, N. Y	24
Elias Sims	Cleveland, Ohio	24
P. Smith	......do	22
Thomas M. Hubble	Saginaw City, Mich	20
Charles S. Barker	Sault Ste. Marie, Mich	20
John Hunter	Sterling Valley, N. Y	19
John Kelly	Cleveland, Ohio	19
T. H. Walsh and Robert J. Hackett	Detroit, Mich	18½
O. J. Jennings	Dunkirk, N. Y	15
M. J. Wilcox	Toledo, Ohio	15
William Richardson	Buffalo, N. Y	12½

Abstract of bids received and opened at 12 o'clock noon of the 26th of May, 1877, for improving harbor at Toledo, Ohio.

Name of bidder.	Residence.	Price per cubic yard.
		Cents.
Patrick Smith	Cleveland, Ohio	20
Edwin H. French	Fulton, N. Y	17
William S. Larkin and Nath. Stickney	East Saginaw, Mich	15½
William Richardson	Buffalo, N. Y	15
Orville J. Jennings	Dunkirk, N. Y	14

The first contract was awarded, with the approval of the Chief of Engineers, to William Richardson, of Buffalo, N. Y., and will expire on the 1st day of October, 1877, and the second to Orville J. Jennings, of Dunkirk, N. Y., which will close on the 31st of August, 1878, and exhaust the appropriation of $60,000 approved August 14, 1876.

There is a light-house on Turtle Island, at the entrance to Maumee Bay, and three sets of range-lights for the same channel; the light which marks the harbor is a fixed white of the fourth order. The nearest defensive work is Fort Wayne, near Detroit, distant 45 miles.

Toledo harbor, Ohio, is in the collection-district of Miami.

Amount of revenue collected during the fiscal year ending June 30, 1877, as follows:

From duties on imports, (coin)	$20,738 93
From other sources, (currency)	6,269 82
Total	27,008 75

Entrances and clearances of foreign vessels during the fiscal year ending June 30, 1877; number, 408; tonnage	117,118 tons.
Entrances and clearances of American vessels from and to foreign ports; number, 98; tonnage	14,934 tons.
Entrances and clearances of coasting-vessels; number, 2,713; tonnage of same	762,286 tons.
Total vessels, 3,219; tonnage	894,338 tons.

Money statement.

July 1, 1876, amount available	$4,180 67
Amount appropriated by act approved August 14, 1876	60,000 00
	64,180 67
July 1, 1877, amount expended during fiscal year	13,411 32
July 1, 1877, amount available	50,769 35
Amount (estimated) required for completion of existing project	110,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	110,000 00

E E 3.

IMPROVEMENT OF PORT CLINTON HARBOR, OHIO.

As by data furnished in previous reports by the officers in charge, a survey and estimate for the improvement of this harbor were made in 1867, and printed in the Report of the Chief of Engineers for 1868. The estimate (approximate) was $89,000. A second survey (with a new project and estimate) was made in 1870; (see Report of Chief of Engineers for 1871;) the estimated cost of this project was $120,000. The plan first adopted consisted in deepening by dredging to the depth of 8 feet the long and narrow channel leading from the mouth of Portage River into deep water of the lake; also by running a timber revetment 1,000 feet in length along the peninsula on the north side of the river at its entrance for the purpose of protecting it against abrasion by the waves from the lake side, and to act as an impediment to the constant encroachment or drifting of the sand into the channel. The first appropriation for the work was made in 1872, and the work of dredging was then commenced; the cut made, however, was soon filled up by the washing back into the channel of the material taken out. Subsequently the revetment or catch-sand fence, on the spit forming the left side of the entrance to the river, was constructed and has answered the purpose in checking the movement of sand very satisfactorily. The plan now adopted for the improvement, in connection with the revetment to which reference has just been made, consists in forming an artificial

harbor by confining the flow of the river and directing the course of its current toward the nearest point of deep water of the lake; about along the line where formerly the oldest known channel existed. For this purpose it is intended to build a canal, faced on each side by a revetment, or strong sheeting of thick plank, strongly supported by rows of closely driven piles; the whole firmly framed together by heavy timber and protected at the bottom by fascines or mill-clippings, loaded down by riprap of loose blocks of stone to resist the action of the current, thus preventing undermining. The work on this plan was commenced in 1875, and continued until the appropriation for that year was exhausted. By the 30th of June the west line of revetment was extended from the end of the first sand-catch fence northeastwardly into the lake for a distance of 840 feet. The anticipated effect of opening a new channel along it, from the scouring effort of the river-current, was only partially successful, the tough clay of the bottom resisting with great tenacity a further tendency toward the accomplishment of that purpose. In constructing it nature must be assisted by dredging out a cut through the canal as soon as the sides are completed. No work was accomplished during the year 1876. The expenditure of the appropriation of $5,000 for that year was not authorized until the early part of May of this one. As soon as a project for the continuance of the work could be submitted to and approved by the Chief of Engineers, after an inspection of the portion executed had been made and careful soundings taken previously to ascertain the effect produced upon the channel by the construction of the first revetment, the necessary arrangements were made for commencing operations as soon as practicable. The material is to be purchased in open market, and the work to be done by day labor. The construction of the second revetment, on the east side of the entrance to the river, was only commenced on the 25th of June, after the necessary piles and timber had been furnished and rafted to the locality. By the end of the fiscal year very little had been accomplished. The length of the new revetment, similar in construction to the one already in position, will be built out as far as the very limited appropriation will admit; it will terminate in a bulkhead nearly opposite the first one. For the present a clear way of 150 feet will be left open to enable vessels to use the old channel, the latter to be built across and closed up at some future time, as soon as a new appropriation can be obtained. The width of the artificial harbor along the first section is to be nearly the same as that of the river, over 300 feet, so as not to obstruct too much the flow upon the breaking up of the ice at the opening of spring. The length of that portion of the canal to be completed during the present working-season, probably by the end of August, will be about 800 feet. From its terminal point to a depth of 10 feet of water in the lake, sufficient for present purposes, the distance is about 900 feet. This section of the work, owing to its greater exposure to the action of storms, will have to be constructed with jetties, or the usual crib-work filled with stones, and covered by a flooring of thick plank. Between the jetties of this part the passage-way will be narrowed to 200 feet, so as to give greater velocity to the river-current, and by this means remove to a great extent the deposits which may have a tendency to form in the channel.

Although from the examinations recently made it is evident that the swift current of the river, accelerated by spring freshets, has a tendency already to open a channel along the center of the proposed canal, and on the line of least distance to a suitable depth, still a narrow cut will in all probability have to be dredged throughout its entire length to aid the action of the water.

It is estimated that an appropriation of $75,000 will be necessary for the fiscal year ending June 30, 1879, to insure the entire completion of this work of improvement. It can be safely anticipated that when once accomplished the Portage River, with its waters slightly contracted and its course straightened, will scour by its velocity and keep open the channel, so that little if any work of dredging will be afterwards required. As the jetties will be subjected to severe storms and heavy pressure from the ice of winters, there will no doubt be occasional work needed to repair any damages or destruction that may occur to them; they cannot, therefore, be considered permanent structures, and will always require more or less attention. It can at present be but mere conjecture what amount of commerce and navigation would be benefited by the completion of this particular work; the amount of revenue collected for the last few years has certainly not been large. The following statement shows the amounts appropriated and allotted for this work of harbor improvement, including the fiscal year ending June 30, 1877:

1872	$8,000 00
1873, allotted from appropriation for contingencies of rivers and harbors	2,000 00
1875	5,000 00
1876	5,000 00
Total	20,000 00

The nearest defensive work is Fort Wayne, below Detroit, 60 miles distant. There is a light-house tower in Port Clinton, but the light was extinguished several years ago; the nearest light-house now in use is at Green Island, 10 miles north.

Port Clinton Harbor is in the collection-district of Sandusky, Ohio.

Amount of revenue collected during the fiscal year ending the 30th of June, 1877, $104.55.

Entrances and clearances during the fiscal year ending June 30, 1877: number of vessels, 484; tonnage of the same, 30,223 tons.

Money statement.

July 1, 1876, amount available	$16 20
Amount appropriated by act approved August 14, 1876	5,000 00
	5,016 20
July 1, 1877, amount expended during fiscal year	86 27
July 1, 1877, amount available	4,929 93
Amount (estimated) required for completion of existing project	75,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	75,000 00

E E 4.

IMPROVEMENT OF SANDUSKY CITY HARBOR, OHIO.

From the last annual report, 1876, of my predecessor in charge of this work of improvement, the following extract is made:

The original works of improvement of this harbor consisted in a pier or crib-work for the protection of Peninsula Point, a projection from the north side of Sandusky Bay, between which and Cedar Point, on the southeast, was the entrance to the bay. These works and the point on which they stood have long ago disappeared, having been destroyed by the lake, and in 1859 nothing remained either of point or pier.

The plan subsequently adopted consists in dredging out the natural ship-channel to the eastward of Johnson's Island, known as the west channel. Some discussions were had relative to the merits of what is called the east channel, which runs close around the west end of Cedar Point, and then points in a more direct line toward the city front; but for the reasons assigned in the report of the engineer then in charge the west channel was preferred, although longer and more tortuous.

To render the east channel serviceable a cut of about 700 feet would have to be dredged in its prolongation over a shoal or sand flat having but 5 or 6 feet of water upon it. There is already evidently a tendency on the part of the lake to wash a channel through it. The dredging of the natural channel is now progressing in conformity with the specifications of the plan; the width is to be 200 feet, with a depth of 15. There was no work executed during the working-season of 1876; it was resumed, however, on the 2d of May of this year, a contract having been entered into with Minot Ingalls Wilcox, of Toledo, Ohio, one dredge being then placed in the cut; on the 17th of June a second dredge was also set to work, agreeable to articles of agreement made with Orville J. Jennings, of Dunkirk, N. Y. The two have been operating respectively until the close of the fiscal year in widening the sweeps at the two most prominent elbows of the channel. As soon as the desired width and depth are obtained along the sweeps and reaches between the 15-foot curve at the outer extremity, and the 12-foot curve at the inner end of the cut, it is proposed to extend the latter about 2,500 feet toward the city front along the line of deepest water.

Twenty-six thousand six hundred and seventeen cubic yards of sand and clay have been dredged and removed by scows into deep water of the lake. By the terms of the two contracts, which are exceedingly low this year in comparison with former ones, it is expected to remove by the close of the fiscal year ending June 30, 1878, over 150,000 cubic yards of material from the channel; this quantity when taken out will about finish the section from the 12-foot curve out into the lake. To complete the entire cut until it reaches the line of docks along the city front it is estimated that $20,000 will be required, and that sum can be profitably expended during the fiscal year ending June 30, 1879. What amount of commerce and navigation would be benefited by its completion cannot now be practically determined; the sources of receipt and supply are by the Lake Shore and Michigan Southern, the Cleveland, Sandusky and Cincinnati, and the Sandusky, Mansfield and Newark (Baltimore and Ohio) Railways, and by the lakes. The entire length of the cut is $4\frac{1}{2}$ miles. No estimate for permanent improvement can be given, as the channel, being unprotected on its sides, will gradually fill up unless kept open by dredging.

Abstract of bids for Sandusky City Harbor, received and opened at noon on the 4th day of April, 1877, agreeable to first allotment made from the appropriation approved August 14, 1876.

Name of bidder.	Residence.	Price per cubic yard.
		Cents.
John Hunter	Sterling, N. Y	30
Ezra Williams and John H. Upham	Duluth, Minn	25
John Sims	Cleveland, Ohio	20
P. Smith	do	19
John Kelly	do	18
Edwin H. French	Fulton, N. Y	17
O. J. Jennings	Dunkirk, N. Y	17
Charles S. Barker	Sault Ste. Marie, Mich	16
T. H. Walsh and Robert J. Hackett	Detroit, Mich	13
William Richardson	Buffalo, N. Y	$12\frac{3}{4}$
M. I. Wilcox	Toledo, Ohio	$11\frac{3}{4}$

By the approval of the Chief of Engineers this contract was awarded to Minot Ingalls Wilcox.

Abstract of bids for Sandusky City Harbor, received and opened at noon on the 26th day of May, 1877, agreeable to second allotment from the appropriation approved August 14, 1876.

Name of bidder.	Residence.	Price per cubic yard.
		Cents.
Edwin H. French	Fulton, N. Y	25
Patrick Smith	Cleveland, Ohio	20
William S. Carkin and Natt. Stickney	East Saginaw, Mich	15¼
William Richardson	Buffalo, N. Y	15
Minot Ingalls Wilcox	Toledo, Ohio	14⅞
Orville J. Jennings	Dunkirk, N. Y	11

By the approval of the Chief of Engineers this contract was awarded to Orville J. Jennings.

There is a light-house on Cedar Point, on the south side of the entrance; the light is a fixed white of the fifth order. Fort Wayne, below Detroit, is the nearest defensive work, —— miles distant.

Sandusky City Harbor is in the collection-district of Sandusky, Ohio.

Amount of revenue collected during the fiscal year ending June 30, 1877, $3,128.10.

Entrances and clearances during the fiscal year ending June 30, 1877: number of vessels, 3,215; tonnage, 518,543 tons.

The amounts appropriated in each year, up to and including June 30, 1877, are as follows:

1844	$15,000	1872	$13,000
1852	15,000	1873	25,000
1864	10,000	1874	25,000
1866	38,580	1875	25,000
1870	10,000	1876	25,000
Sum total			201,580

Money statement.

July 1, 1876, amount available	$106 77
Amount appropriated by act approved August 14, 1876	25,000 00
	25,106 77
July 1, 1877, amount expended during fiscal year	3,334 86
July 1, 1877, amount available	21,771 91
Amount (estimated) required for completion of existing project	20,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	20,000 00

E E 5.

IMPROVEMENT OF HURON HARBOR, OHIO.

The improvement of this harbor consists in the building of two parallel piers of crib-work, filled with loose stone and covered with a heavy plank flooring which form the sides of a canal or artificial harbor; it extends from the mouth of the river Huron in a northeast direction for 1,040 feet, until it reaches a depth of 12 feet of water in the lake, and is 120 feet in width; the channel is 12 feet in depth. The work was commenced in 1826 and completed in 1866. Since then some minor repairs have received attention. During the fiscal year no additional work was executed; but an inspection on the last day, the 30th of June, found that several planks of the flooring had been removed, and some stone taken from the crib-work for ballast; the covering on the shore wing of the west pier is almost entirely gone, and a large quantity of the loose stone removed from it. With these exceptions the harbor is in good condition; a small appropriation of $1,000 is required for the

purpose of attending to the few repairs now needed, and in anticipation of similar ones for the fiscal year ending June 30, 1879.

There is a light-house on the head of the west pier, and an elevated walk placed upon the latter for the use of the keepers; the light is a fixed white of the fourth order. Fort Wayne, below Detroit, 70 miles distant, is the nearest defensive work.

Huron Harbor, Ohio, is in the Sandusky collection-district. Judging from the reports of the past years, the amount of commerce and navigation benefited by the completion of this work has not been large.

Amount of revenue collected for year ending June 30, 1877, $42.40.

Entrances and clearances during the year ending June 30, 1877: number of vessels, 124; tonnage, 21,104 tons.

The following statement shows the amount appropriated each year, up to and including 1876, for the work of this harbor improvement:

1826	$5,000 00	1838	$5,000 00
1828	4,413 35	1844	5,000 00
1829	5,935 00	1852	10,000 00
1830	1,880 36	1866	39,000 00
1831	3,480 00	1874	1,500 00
1832	1,500 00	1875	1,000 00
1834	6,700 00		
1836	4,300 00	Total	97,273 71
1837	2,565 00		

Money statement.

July 1, 1876, amount available	$189 17
July 1, 1877, amount available	189 17
Amount (estimated) required for repairs	1,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	1,000 00

E E 6.

IMPROVEMENT OF VERMILLION HARBOR, OHIO.

The plan of this improvement consists partially in the building of two parallel piers from the mouth of the Vermillion River, which stretch northerly into the lake, forming the sides of a canal. The latter, as now completed, terminates in 12 feet of water; its length is very nearly 1,250 feet and width 100 feet. The work has been extended at different times to its present dimensions. To complete the improvement, the channel between the entire length of the piers and beyond their heads has still to be deepened at places to the required depth of 14 feet and proper width of 100 feet, by blasting and removal of rock from its bottom, also by the dredging of sand and gravel deposited along its length, and out into the lake as far as the 14-foot curve. Some slight repairs are required to the east and west piers. Owing to the smallness of the appropriation, and it being deemed to the best interest of the Government, it was recommended to the Chief of Engineers, and approved by him, that the improvement as commenced be carried on until the funds become exhausted; the material for the work to be purchased in open market, and that it be executed by hired labor.

As the authority for its application was only received in May, and some little time being exhausted in the preparation of a project for its expenditure to be submitted for the required approval, it was late in the fiscal year before any action could be taken toward the accomplishment of the work. At the close of the year no proposition had been definitely made by any of the parties competent to perform the labor required,

although terms for blasting and dredging had been invited from those engaged in the business. Among the reasons assigned for not being willing to undertake the work were that the amount appropriated is too small to pay for the extra expense of fitting out a dredge with the necessary appliances for blasting under water, and that the cost and risk in sending it to and bringing it back from the locality were too great for the small amount of work to be done; these expenses would demand a price that would seem excessive.

As soon as the necessary arrangements can be made, the improvement will be continued as rapidly and as far as possible during the present working season. To finish drilling, blasting, and removal of rock, and the dredging of sand and gravel from the bed of the channel, together with making such repairs to the piers as may be needed, it is estimated that $10,000 will be required for the present to thoroughly complete this work of improvement; some dredging of sand and repairs of wood-work will be annually necessary, in consequence of damage which may result from exposure to heavy storms and the crushing action of the ice in winter. The first appropriation for this work was made in 1836. The piers have from time to time been lengthened, in order more fully to meet the necessities of trade, but it is believed that no further extension will be required for years to come. During the months of September and October, 1876, both the north and east piers were repaired under the direction of my predecessor, and a cut which had been washed through the sand at the shore-end of the west pier was closed to prevent any material from being carried into the channel.

For the last few years the revenue collected has been small, and the entrances and clearances of vessels have not been large, nor has there been any apparent increase since the piers have been completed. What amount of commerce and navigation will be benefited in the future will have to be left to conjecture. Stone and lumber are the principal materials shipped to and from this port.

There is a light-house built on the head of the west pier, and an elevated walk constructed on the latter for the use of the keepers; the harbor is marked by a fixed white light of the fourth order. Fort Wayne, below Detroit, 80 miles west, is the nearest defensive work. Vermillion Harbor is in the Sandusky collection-district.

Amount of revenue collected during the fiscal year ending June 30, 1877, $32.55.

Entrances and clearances during the fiscal year ending June 30, 1877: number of vessels, 87; tonnage of same, 10,804 tons.

The following statement shows the amount appropriated each year, up to and including the 30th of June, 1877, for the work of this harbor improvement:

1836	$10,000 00	1874	$3,000 00
1837	20,000 00	1875	10,000 00
1838	23,626 57	1876	5,000 00
1866	15,315 74		
1872	5,000 00	Total	103,942 31
1873	12,000 00		

Money statement.

July 1, 1876, amount available	$125 45
Amount appropriated by act approved August 14, 1876	5,000 00
	5,125 45
July 1, 1877, amount expended during fiscal year	1,011 60
July 1, 1877, amount available	4,113 85
Amount (estimated) required for completion of existing project	10,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	10,000 00

E E 7.

IMPROVEMENT OF BLACK RIVER HARBOR, OHIO.

The plan for this improvement consists in the construction of two piers from the mouth of Black River, inclosing a canal of 150 feet in width, and extending 1,350 feet in a northwesterly direction into the lake, until a depth of 15 feet of water is obtained; the channel-way has also been dredged to that depth throughout. The piers are formed of cribs, heavily framed and filled with loose stone; also a heavy superstructure of plank being placed upon them. This work may be considered as completed so far as may be required of vessels now employed in the trade of the lakes. Repairs to the piers will be occasionally required, as they are likely to be more or less damaged by the severe gales and the crushing force of ice during the winter months; the channel within and without the piers may need dredging at times. This work of improvement was commenced in 1828, but it appears that the present project was not entered upon until 1864. The piers have been lengthened from time to time, and the channel dredged to sufficient depth, so that this harbor may now be considered as having been extended into the lake as far as it appears desirable.

The coal trade at this harbor has been increasing very rapidly, according to information recently furnished, but what amount of commerce and navigation will be benefited by enlarging the dimensions of the harbor it is impossible to estimate. The greater part of the last appropriation, that of 1876, was expended under the direction of my predecessor, in repairing the damage to the piers caused by a severe gale from the northeast in May of that year, and in closing by a pile-dam a cut washed out by the lake waters at the south or shore end of the east pier, through which material was being carried into the canal. Some repairs are still needed at the south end of the west pier. In order to execute the required work and to have funds on hand to meet similar emergencies during the fiscal year ending June 30, 1879, it is estimated that $1,000 might be advantageously appropriated.

There is a light-house erected at the entrance to the harbor on the head of the west pier; the light is a fixed white light of the fourth order. The nearest defensive work is Fort Wayne, below Detroit, 80 miles distant.

Black River Harbor is in the collection-district of Cuyahoga. The amount of revenue collected during the fiscal year ending June 30, 1877, $1,120.80. Entrances and clearances during the fiscal year ending June 30, 1877, 412 vessels; tonnage of same, 79,359 tons.

The following statement shows the amount appropriated in each year up to and including 1876:

1828	$7,500 00	1852	$5,000 00
1830	8,559 77	1864	20,000 00
1831	9,275 00	1866	10,000 00
1832	8,000 00	1872	20,000 00
1833	2,400 00	1873	20,000 00
1834	5,000 00	1874	20,000 00
1835	4,400 00	1875	10,000 00
1836	6,660 00	1876	6,000 00
1837	6,410 00		
1838	5,000 00	Total	174,204 77

Money statement.

July 1, 1876, amount available	$56 41
Amount appropriated by act approved August 14, 1876	6,000 00
	6,056 41
July 1, 1877, amount expended during fiscal year	6,003 52
July 1, 1877, amount available	52 89
Amount (estimated) required for completion of existing project	1,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	1,000 00

APPENDIX F F.

ANNUAL REPORT OF LIEUTENANT COLONEL CHARLES E. BLUNT, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Buffalo, N. Y., July 12, 1877.

GENERAL: I have the honor to transmit herewith my reports of operations at the harbors of Lake Erie which were in my charge during the whole of the fiscal year ending June 30, 1877, viz, those east of Black River, Ohio.

The harbors west of Cleveland were also in my charge up to December 1, 1876, on which date I transferred them to Maj. N. Michler, Corps of Engineers.

Very respectfully, your obedient servant,

CHS. E. BLUNT,
Lieutenant-Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

F F 1.

CONSTRUCTION OF BREAKWATER IN CLEVELAND HARBOR, OHIO.

For this important city an exterior harbor has been projected, the present harbor room in the narrow channels of the Cuyahoga River being very limited. The new work will be a breakwater, starting from the lake shore at a point about 700 feet west of the end of the old channel of the Cuyahoga, extending northerly into the lake to the 5-fathom curve; thence eastwardly nearly parallel to the shore-line to a point on the prolongation of the line of the old west pier, which will be extended so as to leave an entrance 300 feet wide between its extremity and that of the new work. A safe inclosed harbor, with ample room for shipping and wharves, will thus be formed. The estimated cost of this work, as approved, is $1,800,000. Two appropriations have been made: $50,000 by act of March 3, 1875, and $50,000 by act of August 14, 1876. At the date of last year's report work was going on (under contract previously made) at the pile pier which forms the shore end of the breakwater.

Since that date the remainder of the pile pier (667 feet) has been completed and riprapped on both sides with heavy stone, in accordance with the plans. Besides this, three cribs (each 50 feet long) have been sunk on the prescribed foundation of rubble-stone, filled with stone, and riprapped. The superstructure of the inner of these cribs has been finished, and that of the other two partially built and filled with stone, and one of them temporarily decked over. The outer one is loaded with heavy blocks of riprap stone to protect it from ice.

Eleven hundred and fifty running feet of the breakwater are thus nearly finished.

New proposals having been invited by advertisement for continuation of the work, those received were opened May 7, 1877, and the contracts were awarded to the lowest bidders, Messrs. Farris & Garfield, of Painesville, Ohio, and Mr. W. H. McCurdy, of Cleveland, Ohio—the latter for the iron.

Under these contracts it is proposed to extend the breakwater 300 feet during the coming year.

An improvement of the magnitude of this at Cleveland should be pushed to completion as rapidly as possible. Due regard to economy of construction is of itself a sufficient argument for annual appropriations much larger than those of the last two years, ($50,000 each.) Two hundred thousand dollars are asked for as the next allotment.

Amount required for completion of project, $1,700,000; amount that can be profitably expended during the next fiscal year, $200,000.

Cleveland Harbor, Ohio, is in the collection-district of Cleveland. The main light-house is within city limits, and there are two beacons on the piers. The nearest defensive work is Fort Wayne, below Detroit, 110 miles distant.

Amount of revenue collected during the fiscal year ending June 30, 1877, $106,046.58.

Entrances and clearances during the fiscal year ending June 30, 1877, 4,987; tonnage of same, 2,291,356 tons.

Abstract of contracts.

Contract with Farris & Garfield, of Painesville, Ohio, for furnishing material and labor for the construction of a section of breakwater, dated May 23, 1877, expires September 30, 1878.

Contract with W. H. McCurdy, of Cleveland, Ohio, for furnishing iror material for construction of a section of breakwater, dated May 23, 1877, expires August 1, 1877.

Abstract of contracts for each class of material and labor.

1. Pine timber and lumber, per thousand feet, board-measure	$18 25
2. Hemlock timber and lumber, per thousand feet, board-measure	18 25
3. Rubble-stone, per cord	4 45
4. Block-stone, per ton	1 20

Contract dated May 23, 1877:

	Cents.
1. Screws and washer-bolts, per pound	3
2. Drift-bolts	$1\frac{7}{10}$
3. Spikes	$2\frac{65}{100}$

Money statement.

July 1, 1876, amount available	$33,426 26
Amount appropriated by act approved August 14, 1876	50,000 00
	83,426 26
July 1, 1877, amount expended during fiscal year	48,152 98
July 1, 1877, amount available	35,273 28
Amount (estimated) required for completion of existing project	1,700,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879, for continuing breakwater and for incidental repairs of harbor	200,000 00

F F 2.

REPAIRS OF EAST PIER, CLEVELAND HARBOR, OHIO.

The two piers at the mouth of the Cuyahoga River constitute the original improvement of this harbor. Their inner or land ends, being backed by made land, are no longer of much importance as piers. The inner end of the original east pier, south of the masonry foundation formerly occupied by the beacon, is now, and has been for many years, nothing

more than a revetment, back of which are railroad tracks and buildings. One railroad company in particular (the Cleveland and Pittsburgh) has for many years made use of the pier (or revetment) in such a way that repairs by the United States were scarcely practicable. This portion of the pier has consequently not been considered in expending appropriations. The outer portion, north of the old beacon foundation, was thoroughly repaired in 1874-'75; this outer portion being really the only east pier proper.

In consequence of too deep dredging close to the pier by contractors employed by the city, and, in addition, the improper use of the iron snubbing-posts by vessels, the stone face of the pier was loosened and finally a breach was caused. This breach in no way endangered the harbor or channel, for it was quite impossible that the lake could ever break through from the east, but representations were made that there *was* danger from that cause, and an appropriation of $8,000 was made in the river and harbor bill which became law August 14, 1876, for "the repair of this east pier."

The Secretary of War was at the same time authorized to make an agreement with the Cleveland and Pittsburgh Railroad Company for the future use and occupancy of the pier by that road upon reasonable and just conditions.

A commission was constituted by the President, composed of the collector of customs, the district attorney at Cleveland, and the engineer officer in charge of the harbor, who drew up an agreement which was approved by the Secretary of War.

By this agreement the sum appropriated, or as much of it as necessary, is to be expended in repairing the pier, and the railroad company is to be permitted to use it for the future, right of way to the outer or lake end being reserved to the United States, and the company to keep it in order hereafter.

Under this agreement repairs were commenced in April, and are now well advanced. They will be completed in July. A substantial pile-work capped with timber, and connected with brace pile in rear along 400 feet of the face of the original pier, is the main feature of the work.

No additional appropriation is required.

Money statement.

Amount appropriated by act approved August 14, 1876	$8,000 00
July 1, 1877, amount expended during fiscal year	4,495 75
July 1, 1877, amount available	3,504 25

F F 3.

IMPROVEMENT OF FAIRPORT HARBOR, OHIO.

The appropriations for this harbor (the mouth of Grand River, Ohio) from 1825 to 1876, inclusive, have amounted to $209,670.18, and have been expended in the construction, extension, and repair of two entrance-piers, and in dredging.

The appropriation of August 14, 1876, was $5,000. It has been applied during the year as follows: The old west pier, built in 1828, which was practically destroyed above the water, has been repaired for a length of 448 feet south of the inner end of the new west pier, by putting

in new timber and filling with stone to a height of 2 feet 6 inches above the water.

Inside of the pier a line of piling, capped by timber and backed by sheet-planking, has been constructed to prevent the sea from breaking into the river during severe storms, and also to keep out the sand, which has heretofore drifted into the channel in large quantities.

About five-eighths of this sand has been removed from the channel in front of the old pier.

A catch-sand fence, 4 feet in height above the decking, and 598 feet long, has been built along the inner line of the new portion of the west pier to prevent the sand from blowing over the pier into the channel. The accretion of beach on the west side of the pier is extraordinary. It has filled up to a level with the top of the pier for several hundred feet, so that sand has been blowing over in considerable quantities.

These operations were commenced last fall, as soon as the appropriation was made available, and continued until stopped by the weather. They were resumed in April, and suspended on the 20th of June, the funds having been exhausted.

The southern end of the old west pier has almost wholly disappeared, but as it is backed by solid ground over which the sea never flows, I do not consider its rebuilding a necessity, and make no estimate for it. If, however, the full amount of last year's estimate ($8,000) had been granted it could have been well expended on the line of the pier which is still useful, and in removing the remainder of the sand in the channel in front of it.

The bar at the entrance of the river was not removed by the spring freshets this year. Its position shows clearly to my mind that an extension of the east pier (referred to in previous reports) would cause its removal, for which, otherwise, dredging must be resorted to.

The superstructure of the *east* pier is rapidly decaying, and there is no doubt that in a year it will need considerable renewal and the replacing of lost stone.

For these objects an appropriation of $5,000 is needed, and no more will, it is hoped, be required until it shall be decided to extend the east pier.

Fairport Harbor, Ohio, is in the collection-district of Cuyahoga. There is a stone (lake coast) light-house on the east side, and a new beacon on the end of the east pier. Fort Wayne, 130 miles west, is the nearest defensive work.

Amount of revenue collected during the fiscal year ending June 30, 1877, $27.40.

Entrances and clearances during the fiscal year ending June 30, 1877, 65; tonnage of same, 7,983 tons.

Money statement.

July 1, 1876, amount available	$2,421 43
Amount appropriated by act approved August 14, 1876	5,000 00
	7,421 43
July 1, 1877, amount expended during fiscal year	7,415 95
July 1, 1877, amount available	5 48
Amount (estimated) required for completion of existing project	5,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	5,000 00

F F 4.

IMPROVEMENT OF ASHTABULA HARBOR, OHIO.

The improvements at this harbor have been the construction, repair, and extension of two parallel piers, and deepening and widening the channel by blasting and removing rock, and dredging. The total amount appropriated from 1826 to 1876 has been $268,902.11.

The only operations during the past year were carried on during the fall of 1876. A severe gale early in September damaged the older portion of the west pier, and the injuries being such as to require immediate repair, the work was taken in hand without delay, without advertisement or contract, and completed in November.

Early in October another gale caused an accumulation of sand across the entrance to the harbor, causing a serious obstruction to vessels. As contract after advertisement would have involved a delay injurious to commerce, this bar was removed by dredging as soon as possible, a dredge owned at the harbor being employed at current prices.

The appropriation of $5,000 of August 14, 1876, was not made available for expenditure until the spring of 1877. It is proposed to expend a part of it during the remainder of this season in building a western pier-head, as stated in my report for 1876. This work has been contracted for. The balance will be available for the removal of such sand-bars as may form at the entrance during the present and the next season of navigation. The action of the lake at the mouth of this harbor being somewhat peculiar, it is not yet certain that both piers should not be further extended: No estimate for this can be made at present.

As the recent inspection of the piers showed the probable necessity of repairs of the older portion within a year, an appropriation of $5,000 is asked for this purpose, and for the removal of sand-bars.

Quite an active trade has grown up at this harbor, the receipts by lake being principally iron-ore, limestone, and lumber, and the shipments coal, which is delivered at the harbor by a recently constructed railroad.

Ashtabula Harbor, Ohio, is in the collection-district of Cuyahoga. It has a new beacon on the west pier. Forts Wayne and Niagara are about equally distant, the first west, and the second east, 150 miles.

Amount of revenue collected during the fiscal year ending June 30, 1877, $404.35.

Entrances and clearances during the fiscal year ending June 30, 1877, 583; tonnage of same, 312,295 tons.

Abstract of contracts.

Contract with Charles H. Strong, of Cleveland, Ohio, for furnishing material and labor, except iron, for the extension of the west pier, dated July 5, 1877, expires December 1, 1877.

Contract with W. H. McCurdy, of Cleveland, Ohio, for furnishing iron material for the extension of west pier, dated July 5, 1877, expires August 15, 1877.

Contract dated July 5, 1877:

1. Pine timber and lumber, per M feet, board measure	$23 00
2. Hemlock timber and lumber, per M feet, board measure	20 50
3. Stone, per cord	5 00

Contract dated July 5, 1877:

1. Screw-bolts, per pound	3 cents.
2. Drift-bolts, per pound	1.85 cents.
3. Spikes, per pound	2.8 cents

Money statement.

July 1, 1876, amount available	$14,623 85
Amount appropriated by act approved August 14, 1876	5,000 00
	19,623 85
July 1, 1877, amount expended during fiscal year	13,039 69
July 1, 1877, amount available	6,584 16
Amount (estimated) required for completion of existing project	5,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	5,000 00

F F 5.

IMPROVEMENT OF CONNEAUT HARBOR, OHIO.

The total appropriations for this harbor from 1829 to 1876 were $106,219.39. The project for improvement was completed in 1871. This project included the construction of two parallel piers only. No dredging has been done, the depth of water in the channel (8 feet) being ample for the commerce of the place.

Some very slight repairs were made on the west pier in May, 1877. Everything is now in fair condition, and no further appropriations will be asked until decay of timber renders considerable repairs necessary.

Conneaut is in the collection-district of Cuyahoga, Ohio. There is a beacon with sixth-order light on the end of the west pier. The nearest fort is Niagara, at the entrance of Niagara River into Lake Ontario, 135 miles distant.

Amount of revenue collected during the fiscal year ending June 30, 1877, $57.40.

Entrances and clearances during the fiscal year ending June 30, 1877, 24; tonnage of same, 1,297 tons.

Money statement.

July 1, 1876, amount available	$68 45
July 1, 1877, amount expended during fiscal year	14 95
July 1, 1877, amount available	53 50

F F 6.

IMPROVEMENT OF ERIE HARBOR, PENNSYLVANIA.

The appropriations and allotments for this harbor from 1824 to 1876, inclusive, amount to $503,941.43. These sums have been expended in the construction, rebuilding, and repairs of piers and breakwaters, in dredging, and in various devices for shore protection.

The appropriation made by act of August 14, 1876, was $40,000, of which $25,000 is still undrawn from the Treasury. It will, however, be required for expenditure during the remainder of the present and next season.

The balance remaining on hand last year, with part of the $15,000 which has been since drawn from the Treasury, has been expended during the present year, as follows: In rebuilding 415 running feet more of the north pier.

In adding to the catch-sand fence on the neck of the peninsula, a

length of (299 + 1,162 =) 1,461 feet. The whole length of this fence is now 5,997 feet, of which 4,663 feet is in a continous line. It is very effective in checking the action of the lake upon the beach, and the portion of the peninsula which it protects may now be considered out of danger from storms. The eastern terminus of the longer line is now at a point where the beach begins to widen, and little immediate danger to the harbor is to be apprehended from the lake action farther east. Still this beach is steadily wearing away, and should be watched. I repeat my opinion of last year that money should always be available for beach protection.

A comparison of the last with previous surveys shows that the main body of the peninsula is increasing in size by the accumulation, on the extreme eastern beach, of the sand which is removed from the "neck." Much sand continues farther on, and has a tendency to form a bar outside the channel-entrance piers.

Dredging has been carried on during the year upon this bar and in the channel in the bay, inside the piers, and is still in progress. This inner artificial channel is similarly situated to those at Sandusky and Toledo, and like them will partially fill up and require partial dredging every year. This year's experience is clearly in this direction. If neglected for five years it is probable that it would entirely fill up to the general level of the bottom of the bay. Twenty-eight thousand five hundred and ninety-four cubic yards have been removed during the year.

The north spit protection, built in 1874–'75, in accordance with the plans of a special Board of Engineers, has not been as effective as was hoped in checking the action of the lake during storms upon this part of the beach. I am inclined to think that an extension of the catch-sand fence adopted for the peninsula would be useful here. The old inner breakwater, built many years ago, of which I have already repaired 500 feet, with favorable results, should, I think, be further rebuilt. (See annual report for 1876.)

The funds available July 1 will be expended in rebuilding not less than 300 feet of the old north pier, in channel dredging, and in such beach protection as may be found necessary during the coming year.

It is not possible to make an estimate for the permanent completion of the improvements at this harbor.

The items of shore protection and of dredging will continue to be uncertain, and the old south pier and breakwater will eventually need considerable renewal.

The item of south pier extension, a work which I consider very desirable, I estimate for as before at $78,000. To rebuild the old breakwater on the bay side of the north spit will cost, as I now estimate, (1,300 feet, at $9, $11,700, say) $12,000. This I also think important. I have referred to it in previous reports.

For repairs of north pier beyond the point to which will extend the repairs to be made this season, I estimate, 300 feet, at $30, $9,000. For additional catch-sand fence there should be not less than $10,000 available.

If the channel continues to fill up as it has during the past year $10,000 will be needed for additional dredging.

The above items make in all $119,000 as a provisional estimate for completion. The works could be most economically carried on if that sum were appropriated at once. However, the south pier extension, though very desirable, as it would probably do away with the necessity of considerable dredging, is not an absolutely necessary immediate im-

provement, and I consequently deduct its cost from the amount I request as the next appropriation, reducing it to $41,000, to be expended on the other items mentioned.

Erie Harbor, Pennsylvania, is in collection-district of Erie, Pa. Seven lights of various orders mark the harbor and channels. The nearest defensive work is Fort Niagara, at the mouth of Niagara River, 120 miles distant.
Amount of revenue collected during the fiscal year ending June 30, 1877, $37,843.51.
Entrances and clearances during the fiscal year ending June 30, 1877, 1,450; tonnage of same, 848,472.

Abstract of contract.

Contract with O. J. Jennings, of Dunkirk, N. Y., dated April 30, 1877, expires September 30, 1878 for supplying one or two steam-dredges, with two dump-scows, and one steam-tug to each dredge, with crews, machinery, and all necessary equipment complete, at $5.44 per hour for each dredge and equipment.

Money statement.

July 1, 1876, amount available	$25,011 06	
Amount appropriated by act approved August 14, 1876	40,000 00	
		$65,011 06
July 1, 1877, amount expended during fiscal year	36,300 98	
July 1, 1877, outstanding liabilities	188 22	
		36,489 20
July 1, 1877, amount available		28,521 86
Amount (estimated) required for completion of existing project		119,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		41,000 00

F F 7.

IMPROVEMENT OF DUNKIRK HARBOR, NEW YORK.

The appropriations for this harbor from 1827 to 1876, inclusive, amount to $427,343.93. They have been expended in the construction, reconstruction, and repair of a west pier, and a breakwater, and in blasting and dredging in the channel.

The estimate of 1873, for the project now under construction, was $275,000. Of this there has been appropriated $88,000, the last appropriation, August 14, 1876, being $18,000.

During the past year the work of blasting and dredging in the channel has been completed, under the contract made with Messrs. Case & Jennings, June 15, 1876, payment for which exhausted the appropriation of 1875.

The channel is now believed to be in good condition, with a width of 170 feet, and low-water depth of 13. It has been a tedious and expensive operation, owing to the peculiar character of the rock stratum, which it was very difficult to break up into masses small enough for the dredge to handle.

Early in December, 1876, the old west pier was damaged by the sea during a severe gale, and it being very important that it should be repaired without delay, an allotment of $2,500 from the appropriation of August 14, 1876, was made for that purpose.

The repairs were immediately taken in hand, and were completed in February.

As the balance of the appropriation ($15,500) was not available for expenditure till late last spring, nothing more has been done during the year.

As soon as this sum became available, however, preparations were made for its expenditure this year, and after advertisement, and opening of proposals, according to law, on the 19th of June, contract was made with Orville J. Jennings, of Dunkirk, for the extension of the breakwater.

It is hoped that under this contract 250 feet can be built during the coming year.

The breakwater is now 940 feet long. To extend it to the so-called east channel (see my previous report) would involve an additional construction of (2,750 — 250 =) 2,500 feet of work, which, if the present low prices continue, could be built for $150,000.

But I feel bound to renew the opinion expressed in my reports for 1875–'76, that this extension is not necessary. In my report for 1875, I stated that 1,000 feet additional, carrying the work to an angle in the line, would be ample for many years to come.

I see no reason for changing the opinions expressed in my report for 1876 respecting the further extension of this work, but if Congress decides to make another appropriation, I respectfully suggest that it would be economical to have sufficient funds to carry the breakwater to the angle 510 feet more. Thirty-one thousand dollars would do this, at present prices, and then the work might be suspended until it is settled whether the wants of commerce require a further addition.

Dunkirk Harbor, New York, is in the collection-district of the same name. A light-house, a lighted beacon, and a day beacon, mark the entrance. Fort Niagara, New York, is the nearest defensive work, distant 70 miles.

Amount of revenue collected during the fiscal year ending June 30, 1877, $266.48.

Entrances and clearances during the fiscal year ending June 30, 1877, 107; tonnage of same, 21,131.

Abstract of contracts.

Contract with Orville J. Jennings, of Dunkirk, N. Y., for furnishing material and labor, except iron, for the extension of the breakwater, dated July 5, 1877, expires June 30, 1878.

Contract with William H. McCurdy, of Cleveland, Ohio, for furnishing iron material for the extension of breakwater, dated July 5, 1877, expires August 15, 1877.

Contract dated July 5, 1877:

1. Pine timber and lumber, per 1,000 feet, board-measure	$20 00
2. Hemlock timber and lumber, per 1,000 feet, board-measure	15 03
3. Oak timber and lumber, per 1,000 feet, board-measure	23 00
4. Stone, per cord	4 50

Contract dated July 5, 1877:

1. Screw and washer bolts, per pound	3 cents.
2. Drift-bolts, per pound	1.85 cents.
3. Spikes, per pound	2.8 cents.

Money statement.

July 1, 1876, amount available	$22,550 74
Amount appropriated by act approved August 14, 1876	18,000 00
	40,550 74
July 1, 1877, amount expended during fiscal year	24,846 12
July 1, 1877, amount available	15,704 62
Amount (estimated) required for completion of existing project	31,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	31,000 00

F F 8.

IMPROVEMENT OF BUFFALO HARBOR, NEW YORK.

The amount appropriated for this harbor up to 1866, inclusive, was $435,643.05, which was expended in building, repairing, and extending two piers at the mouth of Buffalo Creek, (thus forming within the present limited harbor,) in dredging the channel, and in constructing a masonry sea-wall to protect the south beach from the action of the lake.

Since 1866 the sums appropriated, amounting up to 1876, inclusive, to $814,405.04, have been mainly expended in the construction of a new breakwater. The old piers and the channel entrance have also been kept in order during this period, and will require yearly attention hereafter, though after the completion of the break-water and the formation of the exterior harbor they will not be of as much importance as heretofore.

Although the breakwater has been under construction since 1866, the final project was not decided upon until 1874, when the report of the Board of Engineers was submitted and approved. It will be found in the Annual Report of the Chief of Engineers for 1876, Part II, page 569.

The appropriation of August 14, 1876, was only $85,000. An allotment of $45,000 was made, which has been expended during the year, as follows:

1st. The excavation by deep-water dredging of the trench prescribed by the Board of Engineers for the breakwater-foundation, and filling it with gravel and stone as a solid bed for the cribs. One hundred and seventy-five feet of trench were thus dug and filled.

2d. The building, sinking, and filling with stone of three cribs, each 50 feet long, the building of the superstructure upon them and upon the last crib sunk in 1876. This finishes the breakwater to a point 2,924 feet from its northern extremity.

3d. Renewing deck-timbers and planking of portions of the breakwater damaged by ice, logs, &c., during the winter of 1876–'77, and refilling with stone sections of the work which lost it by settlement or washing out by the sea.

4th. Refilling with stone of portions of the pile-pier, which will close the harbor at the south end.

Although considerable sand has accumulated outside the old piers, it has caused no obstructions to vessels during the year, and no dredging has been deemed necessary in that locality.

Up to this time there has been no marked accretion of sand on the south side of the pile-pier, and I still hold the opinion on that point expressed in my last report.

In addition to the items just mentioned, minor repairs have been made to the old north and south piers.

There is still in the Treasury $40,000 of the appropriation of August 14, 1876. It is expected that with this amount the breakwater can be extended 150 feet in 1877–'78. Proposals for this will be opened according to advertisement on the 12th of July, 1877, and contract made with the lowest responsible bidder.

The cost of completing the project for this harbor being estimated at $2,000,000, it would require a generation to finish it at the rate of previous appropriations. It is deemed much more economical to progress more rapidly, and $200,000 is the least sum which I think it advisable to ask for next year.

The position which Buffalo occupies as a commercial city is so well known, that it is not necessary to enter into the details of its business.

Amount required for entire completion of breakwater, $1,815,000.

Amount that can be profitably expended during the next fiscal year, $200,000.

Buffalo Harbor, New York, is in the collection-district of Buffalo Creek, New York. The nearest defensive work is Fort Niagara, New York, at the entrance of the Niagara River into Lake Ontario, 26 miles distant. There are three lights, as guides, for the harbor.

Amount of revenue collected during the fiscal year ending June 30, 1877, $295,347.72.

Entrances and clearances during the fiscal year ending June 30, 1877, 4,772. Tonnage of same, 2,698,005 tons.

Money statement.

July 1, 1876, amount available	$10 04	
Amount appropriated by act approved August 14, 1876	85,000 00	
		$85,010 04
July 1, 1877, amount expended during fiscal year	44,994 17	
July 1, 1877, outstanding liabilities	3,493 50	
		48,487 67
July 1, 1877, amount available		36,522 37
Amount (estimated) required for completion of existing project		1,815,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879		200,000 00

APPENDIX G G.

ANNUAL REPORT OF MAJOR WALTER McFARLAND, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Oswego, N. Y., July 28, 1877.

GENERAL: I have the honor to transmit herewith my annual reports upon the public works of improvement in my charge for the fiscal year ending June 30, 1877.

Very respectfully, your obedient servant,

WALTER McFARLAND,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

G G 1.

IMPROVEMENT OF WILSON HARBOR, NEW YORK,

A history of this improvement and a sketch showing its condition at the close of the last fiscal year will be found in the Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

In the fall of 1876 the sea breached the west pier, near its inner end, making an opening 120 feet broad, through which, during the succeeding months, sand and gravel were carried by the action of the sea until the harbor was entirely closed, and upon the breaking up of the ice and the opening of navigation in the spring, a bank of this material 3½ feet above the lake-level and 20 feet wide at the water-line was found to have formed across the channel from pier to pier where there had previously been a depth of 10 feet, completely cutting off from the lake the waters of Twelve-Mile Creek, the mouth of which forms the harbor of Wilson.

The breach thus made is through the old part of the pier built many years ago by private enterprise, before any effort to improve this harbor had been made by the Government of the United States, and which, under the scheme of improvement proposed for this harbor, it was intended to rebuild.

The rebuilding of this part will not increase the cost of the pier-work beyond the amount originally estimated for it, as the removal of all this old work was regarded as necessary, and its cost was included in the original estimate. But the large amount of sand and gravel which has washed into and filled up the channel—amounting to more than 20,000 cubic yards—should be removed, and we may expect that the removal of this, and the repair of other damage that is likely to occur through the action of the sea before the breach in the west pier is filled up, will cost not less than $10,000, and the original estimate will, therefore, be increased by this amount.

No money was available for the prevention of this damage or for the prosecution of the improvement during the year, and no work has, therefore, been done upon it.

By act of Congress, approved August 14, 1876, the sum of $10,000 was appropriated for the improvement of this harbor, but this money did not become available until May 1, 1877.

On the 28th of May authority was given to apply this appropriation by the use of hired labor and by purchase in open market to the repair of the west pier and to dredging the channel. Measures were immediately taken for beginning the work, but the necessary material was not procured until after the close of the fiscal year.

This work of repair will be completed and the appropriation will be exhausted before the close of the present working season.

Wilson Harbor is in the collection-district of Niagara, at the mouth of Twelve-Mile Creek, 12 miles east of the mouth of Niagara River, and 6 miles west of the harbor of Olcott, where is situated the light-house nearest to Wilson Harbor.

The following statement of the commerce of the port for the fiscal year ending June 30, 1877, is furnished from the custom-house records:

Amount of revenue collected	$9 75
Value of exports	1,100 00
No. of vessels entered	15
Their tonnage, tons	708
No. of vessels cleared	16
Their tonnage, tons	749

Value of imports not given.

The deputy collector states also that there were shipped from this port before its destruction, and not reported:

	Bushels.	Value.
Wheat	13,034	$14,504 72
Barley	22,082	17,075 35
Oats	711	228 64
		31,808 71

Money statement.

July 1, 1876, amount available	$166 64
Amount appropriated by act approved August 14, 1876	10,000 00
	10,166 64
July 1, 1877, amount expended during the fiscal year	148 19
July 1, 1877, amount available	10,018 45
Amount (estimated) required for completion of existing project, with the additional $10,000 called for in this report	80,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	80,000 00

G G 2.

IMPROVEMENT OF OLCOTT HARBOR, NEW YORK.

The condition of this work is the same as it was at the close of the preceding fiscal year.

Its history and a sketch of its condition at that time will be found in the Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

Nothing but a very small balance was available for the prosecution of the improvement at the beginning of the year, and nothing has since been appropriated for it. Nothing has, therefore, been expended upon it.

As stated in the last annual report, the existing project of improvement of this harbor provides for the extension of each pier about 100 feet farther into the lake, and the removal of 2,600 cubic yards of sandstone, and 6,000 cubic yards of sand, clay and gravel from between the piers, and 2,500 cubic yards of similar material from the inner basin or harbor, and the estimated cost of this work is $10,000, all of which might be profitably expended within the next fiscal year.

Olcott Harbor is in the collection-district of Niagara, at the mouth of Eighteen-Mile Creek, 18 miles east of the mouth of Niagara River and of Fort Niagara, and is lighted by a sixth-order light, erected near the head of the west pier.

The following statement of its commerce is taken from the records of the custom-house:

Revenue collected during fiscal year ending June 30, 1877	$161 35
Value of imports	1,065 25
Value of exports	971 64
Number of vessels cleared	30
Their tonnage, tons	1,173
Number of vessels entered	28
Their tonnage, tons	1,127

Money statement.

July 1, 1876, amount available	$3,484 20
July 1, 1877, amount expended during fiscal year	3,421 00
July 1, 1877, amount available	63 20
Amount (estimated) required for completion of existing project	10,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	10,000 00

G G 3.

IMPROVEMENT OF OAK ORCHARD HARBOR, NEW YORK.

In the fall of the past year a breach was formed by the sea at the shore end of the east pier, through which from 800 to 1,000 cubic yards of sand and gravel from the outer beach have been washed into the channel, rendering it somewhat crooked, but not materially reducing the mid-channel depth.

In other respects the harbor is in the same condition as at the close of the last annual report.

The history of this harbor and a sketch of its condition at that time will be found in the Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

No money for the prosecution of this improvement, excepting a very small balance, was available at the beginning of this fiscal year, and none was expended except in office-work relating to this harbor.

By act of Congress approved August 14, 1876, an appropriation of $2,000 was made for the improvement of this harbor, $800 of which were made available in the month of October, but the amount was not large enough to admit of the proper protection of the east pier against the action of the sea.

In May following, the remaining $1,200 were made available, and authority was given to carry on the work of repair by the employment of hired labor and by purchase in open market.

This was so near the close of the fiscal year that nothing could be accomplished during the little time that remained.

Since the close of the year arrangements have been made for the expenditure of this appropriation in the repair of both piers, and it is

expected that this will be accomplished before the close of the present working season.

The work still remaining to be done at this harbor is the repair of the piers and the removal of the sand and gravel which has been washed into the channel, which may be accomplished for the amount yet unappropriated of the original estimate, which is $4,000.

Oak Orchard Harbor lies in the collection-district of Genesee, nearly midway between the mouths of the Genesee and the Niagara Rivers, 30 miles distant from the former and about 45 miles from the latter, and forms the only good harbor of refuge lying between these points. It is lighted by a fourth-order light, situated at the outer end of the west pier.

The following statement of its commerce is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1877	$1,215 18
Value of imports	14,050 05
Value of exports	51,508 55
Number of vessels cleared	32
Their tonnage, tons	1,862
Number of vessels entered	31
Their tonnage, tons	1,772

A large number of vessels took refuge here from storms during the year.

Money statement.

July 1, 1876, amount available	$234 64
Amount appropriated by act approved August 14, 1876	2,000 00
	2,234 64
July 1, 1877, amount expended during fiscal year	233 12
July 1, 1877, amount available	2,001 52
Amount (estimated) required for completion of existing project	4,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	4,000 00

GG 4.

IMPROVEMENT OF CHARLOTTE HARBOR, NEW YORK.

A little less than $600 was available for this work at the beginning of the fiscal year, and nearly all of this has been expended; the work done being the replacing of decayed and broken plank and the refilling of piers where stone had been washed out.

The original scheme for the improvement of this harbor has been carried out, and no more money is likely to be called for, excepting so much as may be needed for making repairs from time to time. As the piers are old, their superstructures are now damaged by decay, and with their decay the stone-filling is washed out, and it is probable that the repair of such damage as this will require $1,000 a year for several years to come.

Charlotte Harbor is in the collection-district of Genesee, and is the port of the city of Rochester, 7 miles distant.

The harbor is formed by the mouth of the Genesee River.

For a history and sketch of it see Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

The following statement of its commerce is furnished from the records of the custom-house:

Amount of revenue collected during the fiscal year ending June 30, 1877	$23,880 00
Value of imports	157,068 00
Value of exports	509,840 00

Number of vessels cleared	564
Their tonnage, tons	116,388
Number of vessels entered	554
Their tonnage, tons	116,837

Money statement.

July 1, 1876, amount available	$597 86
July 1, 1877, amount expended during fiscal year	575 32
July 1, 1877, amount available	22 54
Amount that can be profitably expended in fiscal year ending June 30, 1879, in repairs	1,000 00

GG 5.

IMPROVEMENT OF PULTNEYVILLE HARBOR, NEW YORK.

No working balance was available for the improvement of this harbor at the beginning of the fiscal year, and nothing has been expended upon it except in office work.

By act of Congress approved August 14, 1876, an appropriation of $3,000 was made for this harbor, and in May authority was given to carry on the work of improvement by purchase in open market and employment of hired labor. But it was too late to accomplish anything before the close of that fiscal year. It is proposed to apply this money toward closing the opening now existing between the inner end of the east pier and the shore, and to the repair of the inner part of the west pier. This will be done before the close of the present working-season.

A history of this harbor, and a sketch of its condition, will be found in the Annual Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

The work yet remaining to be done is the complete closure of the opening between the east pier and the shore, only a part of which can be done under the last appropriation.

To finish this work as originally proposed will require an appropriation of $18,000, an increase of $9,000 over the unappropriated balance of the original estimate for this harbor, which increase, as stated in the annual report for the fiscal year ending June 30, 1875, is due to the fact that the material met with in dredging the channel was harder and more difficult to remove than had been anticipated, and the cost was, therefore, much greater than the estimated cost as given in the original scheme of improvement.

Pultneyville Harbor lies in the collection-district of Genesee, about 40 miles west of Oswego, and a little over 20 miles east of the mouth of the Genesee River. The nearest light-house is at Great Sodus Bay, about 12 miles east of Pultneyville.

The following statement of the commerce of the port is furnished from the records of the custom-house:

Revenue collected during the fiscal year ending June 30 1877	$666 41
Value of imports	3,468 95
Value of exports	1,838 24
Number of vessels cleared	46
Their tonnage, tons	1,091
Number of vessels entered	43
Their tonnage, tons	1,456

Money statement.

July 1, 1876, amount available	$126 56
Amount appropriated by act approved August 14, 1876	3,000 00
	3,126 56
July 1, 1877, amount expended during fiscal year	87 12
July 1, 1877, amount available	3,039 44
Amount (estimated) required for completion of existing project	18,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	18,000 00

G G 6.

IMPROVEMENT OF GREAT SODUS HARBOR, NEW YORK.

A history of this improvement and a sketch of its condition at the close of the last fiscal year will be found in the Annual Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

During the past year nothing has been done here excepting a few repairs upon the sand-catcher and upon the east and west piers, and nothing remains to be done, under the original scheme of improvement, but the connection of the inner end of the east pier with the shore.

By act of Congress approved August 14, 1876, the sum of $5,000 was appropriated for the improvement of this harbor, but this did not become available until May, 1877. Authority was subsequently given to expend this money in the improvement of the harbor by purchase of material in open market and the employment of hired labor, but so little of the fiscal year then remained that nothing was done before its close. Since then arrangements have been made for the necessary material and labor, and it is expected that before the close of the present working-season all the money available will have been applied to the repair of the west pier and the building of an additional sand-catcher. A quantity of sand has been blown into the channel next the west pier, which must eventually be removed, although there is no immediate necessity for it. It is expected that the repair of the decayed and damaged west pier and the building of the new sand-fence will prevent further deterioration of the channel from this cause.

Great Sodus Harbor is in the collection-district of Oswego, and is distant about 32 miles from Fort Ontario, at Oswego. It is lighted by a fourth-order coast white-flash light on the bluff west of the entrance, and by two white beacon-lights at the ends of the west pier.

The following statement of its commerce is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1877	$637 71
Value of imports	12,488 57
Value of exports	46,699 75
Number of vessels cleared	62
Their tonnage, tons	6,179
Number of vessels entered	63
Their tonnage, tons	6,205

Money statement.

July 1, 1876, amount available	$2,221 12
Amount appropriated by act approved August 14, 1876	5,000 00
	7,221 12
July 1, 1877, amount expended during fiscal year	749 03
July 1, 1877, amount available	6,472 09
Amount (estimated) required for completion of existing project	10,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	10,000 00

G G 7.

IMPROVEMENT OF LITTLE SODUS HARBOR, NEW YORK.

No work has been done here during the past year except closing a breach which had been formed through the west beach; about 70 linear feet of crib-work were required for this purpose.

By act of Congress approved August 14, 1876, the sum of $5,000 was appropriated for the improvement of this harbor, but it was not until May, 1877, that this money became available, and it was then too late to do anything with it before the close of the fiscal year. This money will be applied during the present season to the repair of the west pier, and to the extension shoreward of the inner end of the east pier. Authority has been given to do this work by purchase in open market, and by the employment of hired labor.

The only work yet remaining to be done under the original scheme of improvement is the connection of the inner end of the east pier with the shore, which will require the unappropriated balance of the original estimate, namely, $12,000. A part of the money heretofore appropriated for this work has been necessarily applied to the repair of damage which has occurred from time to time in the work already constructed, and it may become necessary to call for additional funds to replace those so applied.

A history of this improvement, accompanied by a sketch of the harbor, will be found in the Annual Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

Little Sodus Harbor lies in the collection-district of Oswego, about 15 miles west of Fort Ontario, at Oswego. The harbor is lighted by a fixed white light of the fourth order, placed near the head of the west pier.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1877	$3,154 68
Value of imports	22,544 00
Value of exports	86,111 00
Number of vessels cleared	226
Their tonnage, tons	18,258
Number of vessels entered	213
Their tonnage, tons	13,417

Money statement.

July 1, 1876, amount available	$1,289 96
Amount appropriated by act approved August 14, 1876	5,000 00
	6,289 96
July 1, 1877, amount expended during fiscal year	433 39
July 1, 1877, amount available	5,856 57
Amount (estimated) required for completion of existing project	12,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	12,000 00

GG 8.

IMPROVEMENT OF OSWEGO HARBOR, NEW YORK.

Operations at this harbor during the past year have been confined to the construction of the superstructure, 210 feet long; of the six cribs sunk in the extension of the outer breakwater; to the placing one counter-fort in rear of the exposed end of the breakwater; and to extensive repairs to both breakwaters, which had been much damaged by the action of the sea. The repairs to the new breakwater consisted in removing the deck-plank where the structure had settled materially, (the settlement in many cases being 3 and 4 feet,) leveling up the timber-work, filling in with stone, and replacing the deck-plank. Over a large part of the work the stone filling had settled to such a degree that it was necessary to remove the deck-plank, fill in with stone, and then replace the plank. This latter operation, in which no leveling of the timber was required, had to be done over 917 linear feet of the lake arm of the breakwater, and over 413 linear feet of the west half, and 174 linear feet of the east half of the shore arm of the breakwater.

About 700 linear feet of this structure had to be levelled up by bolting additional timbers upon those which had settled.

In the old breakwater, parts of the protecting cribs and counter-forts had to be rebuilt, and the superstructure of the breakwater itself had to be rebuilt from the water-line, on the exposed side, for about 303 feet, while new planking has been laid over 133 linear feet of it.

Beside this, it has been necessary to strengthen this old breakwater in many places by building bulkheads, placing smaller cribs inside the older work, and sheathing the old work outside with plank.

In all these operations there have been expended about—

562,000 feet, board-measure, pine.
110,000 feet, board-measure, hemlock.
1,396 cords of stone.
112,000 pounds of iron.
At a total cost of $40,588.48.

A history of this work and a sketch of its condition at the close of the last fiscal year will be found in the Annual Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

The total length of this breakwater, as now constructed, is as follows:

Shore arm	910 feet.
Lake arm	2,782 feet.
Total	3,692 feet.

And under the project as approved it is to be extended about 2,000 feet more to the eastward, or until its eastern extremity is about on the prolongation of the outer part of the old breakwater.

The original estimated cost of this work was $1,162,682, of which amount there has already been appropriated the sum of $515,000, leaving $557,000 yet to be appropriated, but much of that already appropriated has been applied to the repair of damages to both breakwaters occasioned by storms, as in the past year, where over $20,000 have been so applied, and it is probable that the money thus diverted from original construction will yet be needed before this work is completed.

By act of Congress approved August 14, 1876, the sum of $90,000 was appropriated for the improvement of this harbor, but only so much of this was made immediately available as was necessary for repairing damages already done to the work and for putting it in condition to withstand the action of the usual fall and winter gales. In September

$25,000 were allotted for this purpose, and in November an additional sum of $5,000; and nearly the whole $30,000 were applied to this purpose before winter set in.

The remaining $60 000 were made available in the month of May following, and shortly after authority was given to apply this money to the improvement by the purchase of material in open market and by the employment of hired labor. Nothing was accomplished, however, before the close of the fiscal year, excepting making the necessary arrangements for the supply of materials required.

The amount of the appropriation now available is sufficient to permit the extension of the new breakwater between 400 and 500 feet; and it is hoped that this may be accomplished during the present working-season. This is not certain, however, as there is always difficulty in getting supplies of such timber as is needed in such structures at this season of the year. Twelve-inch timber is rarely kept in stock, and when wanted it is usually necessary to send into the woods and have it cut. This should be done in the winter, as it is a difficult and expensive thing to get it out in the summer season; yet our appropriations are usually so made that this becomes necessary.

Oswego Harbor is in the collection-district of Oswego, and is lighted by a fixed white light of the third order, and by a red beacon-light at the outer end of the old breakwater. Fort Ontario is situated a little to the east of the east pier, and commands the harbor.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1877	$430,748 59
Value of imports	4,122,876 00
Value of exports	1,096,905 00
Number of vessels cleared	2,131
Their tonnage, tons	390,680
Number of vessels entered	2,128
Their tonnage, tons	390,251

Money statement.

July 1, 1876, amount available	$9,058 49
Amount appropriated by act approved August 14, 1876	90,000 00
	99,058 49
July 1, 1877, amount expended during fiscal year	40,588 48
July 1, 1877, amount available	58,470 01
Amount (estimated) required for completion of existing project	557,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	300,000 00

GG 9.

IMPROVEMENT OF OGDENSBURG HARBOR, NEW YORK.

The history of this work will be found in previous reports, and a sketch of its condition at the close of the last fiscal year will be found in the Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

The original scheme of improvement provided for the dredging of certain parts of the channel and harbor, and for the construction of pile-piering to prevent the waters of the Oswegatchie from wasting their force by spreading over the shoal which lies in front of the city.

The dredging has been essentially completed, and there appears to be no present necessity for constructing the proposed pile-piering, the estimated cost of which is about $70,000.

Nothing has been done in this improvement during the past year, as there was no working balance available at its beginning, and no appropriation has since been made for it.

Ogdensburg Harbor is in the collection-district of Oswegatchie, about 120 miles from Fort Ontario, at Oswego, and is lighted by a fixed white light of the fourth order.

The following statistics of its commerce are furnished from the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1877	$74,567 83
Value of imports	468,476 00
Value of exports	790,883 00
Number of vessels cleared	927
Their tonnage, tons	165,004
Number of vessels entered	948
Their tonnage, tons	160,799

Money statement.

July 1, 1876, amount available	$59 10
July 1, 1877, amount expended during fiscal year	44 02
July 1, 1877, amount available	15 08
Amount (estimated) required for completion of existing project	70,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.	70,000 00

G G 10.

IMPROVEMENT OF WADDINGTON HARBOR, NEW YORK.

The history of this improvement will be found in the Reports of the Chief of Engineers for the fiscal years ending June 30, 1873, 1874, 1875, and 1876, and a sketch of the harbor in its present condition will be found in the last-named report.

The work of improvement is completed as originally designed, and nothing more is needed here. No work has been done during the past year, and the small balance of $42.72 on hand at the beginning of the fiscal year has been expended in office supplies.

Waddington Harbor is in the collection-district of Oswegatchie, on the Saint Lawrence River, about 20 miles below Ogdensburg, where the nearest American light-house is situated. It is about 100 miles from Fort Montgomery, at Rouse's Point.

The following statistics of its commerce are furnished by the records of the custom-house:

Amount of revenue collected during the fiscal year ending June 30, 1877	$3,075 14
Value of imports	32,277 00
Value of exports	5,453 00
Number of vessels entered	3
Their tonnage, tons	130
Number of vessels cleared	3
Their tonnage, tons	130

Existing project completed; nothing required.

Money statement.

July 1, 1876, amount available	$42 72
July 1, 1877, amount expended during fiscal year	42 72

APPENDIX H H.

ANNUAL REPORT OF MAJOR G. H. MENDELL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
San Francisco, Cal., July 7, 1877.

GENERAL: I have the honor to inclose the annual reports for the year ending June 30, 1877, of the works of river and harbor improvement under my charge.

Very respectfully, your obedient servant,

G. H. MENDELL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

H H 1.

IMPROVEMENT OF OAKLAND HARBOR, CALIFORNIA.

The operations for the past year have been mainly directed to the attainment of a convenient depth in the channel between the jetties, which is very much needed by the growing commerce of Oakland.

It was proposed to excavate a channel 200 feet wide from the 10-foot curve in San Francisco Bay to the 10-foot curve in Oakland Harbor. The length of the line of dredging is 6,300 feet.

This channel has been opened for a width of 100 feet, and the second cut of the same width is now nearly completed, only 900 feet remaining to be excavated, involving about 15,000 yards.

The dredging was commenced under a contract with John A. Ball at the rate of 24 cents a yard. This contract was nullified on the 12th September, 1876, in consequence of the failure of the contractor to prosecute the work at the rate provided by the terms of the agreement.

Between July 1 and September 12 the contractor excavated 3,744 cubic yards with a single dredge.

The Western Development Company undertook the work, after it was taken out of the contractor's hands, at the price he had received, namely, 24 cents per yard. The company placed two dredges at work, and some time subsequently added a third, by the aid of which the work embraced in Mr. Ball's contract was nearly completed in the required time, viz, April 1, 1877. In the mean time the growing demands of commerce seemed to require a greater width than 150 feet, which was the width originally contemplated, and it was thought advisable to give a width of 200 feet to the channel. The company continued to work under the

original agreement to June 1, 1876, at which time, after advertisement and call for bids, they being the only bidder, a written contract was made for the part remaining undone at the rate of 35 cents per yard.

This contract is now in force, and it is expected that the work will be completed in July, 1877. The total amount dredged during the year was 196,465 cubic yards.

At the same time that the dredging remaining to be done was advertised for bids, tenders were invited for about 20,000 tons of stone for the extension of the training-walls or jetties. There were a number of bidders, a list of whom is appended. The award was made to the lowest bidder, Tilford & Terkelson, at $1.19 per ton.

These parties began work about the middle of June, and to the close of the month they delivered 2,335 tons, which were placed on the south wall, extending it 400 feet. The stone comes in part from Angel Island and partly from Telegraph Hill.

It is estimated that the work now in progress will consume all the money that is at present available.

Several important parts of the construction await a liberal appropriation on the part of Congress.

The part of the jetties above low-water will, it is thought, necessarily be made of concrete masonry. A dry stone wall, with the material available in the quarries near the city, cannot be made to keep its shape.

The excavation of the tidal basin above Oakland to a depth of 1 or 2 feet below low-water ought to be undertaken before long, in order to secure a larger tidal prism. It is hoped that cheapened dredging, combined with the reclamation of the low lands in the vicinity, which will need the material taken from the bay, will permit the work to be done at a low price.

No further steps have been taken to condemn the land for a canal to connect with San Leandro. The appropriation being too small to permit any new work to be undertaken, there has been no urgency in obtaining possession of the land.

The establishment of lines on both sides of the estuary, beyond which no constructions can be permitted, was referred to in the last annual report, and has received considerable attention since that date. This has resulted in the establishment, so far as this office can establish, of a line from the present wharves to the head of the jetty on the Oakland side.

The fixing of this line has been urgent, many building operations being dependent upon it and awaiting its establishment. This line is established on sound principles and in harmony with the views of the water-front company, as represented by their engineer. This gentleman, Calvin Brown, civil engineer, has also been consulted in regard to the lines which it is proposed to establish wherever the property of the water-front company extends. General Alexander, the senior engineer on the Pacific coast, has also given the benefit of his views on the same point.

There seems to be every reason to expect that the difficulties which were described in the last annual report, resulting from ownership, real or fictitious, of the bed of the estuary by private parties, under grants of the legislature of the State, will be obviated by the formal assent of the parties to the establishment of certain lines, outside of which the ownership and sovereignty of the United States will be admitted. This done, there will be no reason why the work should not again receive its share of favor from Congress.

The accompanying map [not printed in this report] exhibits the train-

ing-walls, and the channel which has been excavated. The depth has been well maintained, and in some instances it has been increased.

The accompanying statistics represent the condition of commerce in the estuary, and on the main pier outside, during the past year. The statistics for the estuary proper have not been thoroughly segregated in past years, so that their growth cannot be represented. The number of vessels in 1876, leaving out one wharf which kept no record, was 2,520, while in 1875 the number was 2,144. The increased depth of the channel admits larger vessels than could enter before 1876.

On a spring-tide 17 feet can be carried into the harbor.

The largest vessel that has yet entered was a French bark, drawing 14 feet.

Oakland is in the collection-district of San Francisco, and only five miles distant. The nearest fortifications and light-houses are in the harbor of San Francisco.

Money statement.

July 1, 1876, amount available	$47,157 50	
Amount appropriated by act approved August 14, 1876	75,000 00	
		$122,157 50
July 1, 1877, amount expended during fiscal year	59,192 26	
July 1, 1877, outstanding liabilities	1,062 56	
		60,254 82
July 1, 1877, amount available		61,902 68
Amount (estimated) for completion of existing project		1,539,529 20
Amount that can be profitably expended in fiscal year ending June 30, 1879.		200,000 00

COMMERCIAL STATISTICS OF THE OAKLAND CITY FRONT.

New wharf, Foster & Gellet's Wharf.

Period.	No. of vessels.	Lumber.	Lime.	Hay and grain.	Coal.	Sand.	Brick.	Wood.
		M.	*Barrels.*	*Tons.*	*Tons.*	*Tons.*	*M.*	*Cords.*
1877. April 1 to June 30	110	642	4,300	284	400	2,400	380	100

La Rue's Wharf.

Year.	No. of vessels.	Lumber.	Lime.	Jute.	Coal.	Shingles.	Laths.	Wood.
		M.	*Barrels.*	*Tons.*	*Tons.*	*M.*	*M.*	*Cords.*
1875	883	7,250	2,000	900	5,500	3,800	2,500	2,000
1876	912	9,000	....	....	7,500	4,000	3,000	....

City Wharf.

Year.	No. of vessels.	Lumber.	Produce.	Coal.	Wood.	Brick.
		M.		*Tons.*	*Cords.*	*M.*
1873	431	400	283	10,823	3,215	3,218
1874	605	2,475	1,282	12,263	3,867	3,797
1875	896	4,747	2,130	16,885	4,040	5,061
1876	1,223	7,566	4,951	18,848	4,046	5,647

Taylor & Co.'s Wharf.

Year.	No. of vessels.	Lumber.	Shingles.	Laths.
		M.	M.	M.
1875	162	8,933	2,000	....
1876	150	9,000	5,193	1,355

Merritt's Wharf.

Year.	No. of vessels.	Lumber.	Shingles.	Laths.
		M.	M.	M.
1875	209	7,449	4,254	2,177
1876	125	10,000	4,000	2,000

Muir's Wharf.

This wharf has done a large shipping business, but has so far kept no accounts whatever of traffic. Estimates coal at 3,600 tons.

Main Pier or Ferry Wharf.

Total number of passengers over Oakland Ferry:

In 1872	2,611,418
In 1873	2,841,374
In 1874	3,446,429
In 1875	4,309,712
In 1876	5,000,000

Bullion valued at $35,000.

General freight.

Description.	1875.	1876.
Merchandise .... tons..	496,594	469,400
Grain exported .... do...	89,991	131,481
Coal imported .... do...	22,885	40,240
Totals	609,470	641,121

STATEMENT OF BIDS RECEIVED AND OPENED ON THE 16TH DAY OF MAY, 1877, FOR DREDGING AND FOR DELIVERY OF STONE.

Dredging.

1 bid by Western Development Company at 35 cents per cubic yard.

Delivery of stone.

Tilford & Terkelson, per ton	$1 19
Newland & Shanon, per ton, from Angel Island	1 23
Newland & Shanon, per ton, from Yerba Buena	1 24½
R. P. Kelley, per ton	1 47
Bradley Muir, per ton	1 48

H H 2.

IMPROVEMENT IN WILMINGTON HARBOR, CALIFORNIA.

DREDGING.

Dredging was mainly confined to the reef of clay and stone which crosses the entrance of the harbor from Deadman's Island to the shore. There were taken from this reef 4,561 yards of clay and 4,601 yards of stone. There were also dredged 2,273 yards of sand, part of which was taken from the reef and part from a narrow trench which was started above the reef and carried for several hundred feet to a depth of 12 feet. This trench was abandoned for two reasons, namely, want of funds and from a fear that the sand would be washed out of the interior channel faster than the forces outside could dispose of it. If this were the result the sand would be apt to accumulate at the mouth of the harbor.

There is now a fair equilibrium under which the sandy part of the channel deepens slowly and regularly, and the sand is carried to the west of the entrance, where it is building up a shoal.

The first cut through the reef was 100 feet wide and 12 feet deep. This was finished in July. A second cut was started 100 feet wide and 14 feet deep. This was made for 130 feet, when it was reduced to 50 feet in width and 12 feet in depth. This reduction was made because the available funds were insufficient. This reduced cut was finished in January, 1877, and there is now a channel 150 feet wide through the reef, with 12 feet of water at mean low tide of the Coast Survey, or 10 feet at the lowest known tides.

The stone and clay taken from the reef were used to build a training-wall on the west side of the channel. In addition 2,400 tons of stone were purchased and placed on this wall. The wall runs parallel with the channel for 800 feet, and was built to 3 feet above low-water. It has settled to some extent and is now one foot lower.

Some stone was placed on the main jetty, near the end of the timber-work, to raise it to the height of the rest of the line. A groin on the sea-side of the end of the timber-work was extended and raised in stone, and some stone was used in connection with our operations in brush. All of these last-named operations consumed 850 tons of stone.

The accumulation of sand on the seaward side of the work has not been so rapid as was expected, nor as is desirable. Some desultory operations have been carried on from time to time with the view to hasten the growth of the dunes. Brush has been used for this purpose in various forms and with moderate success. The subject has hardly received a fair trial, nor have any positive rules for the application of brush to this purpose been developed.

It is believed that a good deal can be done in this way to hasten the desired result, but more time and some money must be available to prove the assertion.

Nine groins of fascines were extended from the main work, each 70 feet long, and each of two tiers of fascines. They were aligned parallel to the crests of the waves. Two courses of tides—that is one month—filled the sand to the top of the brush. This was very well, but it was quite expensive.

The cost of making fascines and of stone to load them was considerable, and another experiment was tried.

The brush was cut to 3 feet lengths and set up on end in a trench 2 feet deep, leaving the brush projecting 1 foot above the beach. The

alignment, as before, was parallel to the wave front. The brush was held in place by packing the sand in the trench firmly. This is inexpensive and produces good results.

Some other experimental applications of brush were made. These operations consumed 80 cords of brush and accumulated about 6,400 cubic yards of sand.

The channel has been steadily improving both in width and depth. There is now a depth of 8 feet at mean low water where there was less than 2 when the original operations were commenced. The increase in depth during the year has been 1 foot.

The 9-foot curves inside and outside are now but 600 feet apart, having approached each other 500 feet during the year.

At high-water of spring tides, there is a depth of 16 feet in the shoalest place; and at other high waters, 12 to 14 feet, as the tides are neap or vary to spring.

These depths are sufficient to admit all of the coasting-vessels, and it is now a common practice with all of them except the passenger-steamers to enter the harbor.

In November, 29 vessels entered the harbor. Two of them drew 14 feet, and 20 drew 13 feet.

It is probable that the deepening of the channel will now proceed slowly, as it has done since the currents have been controlled, and two or three years will probably give a minimum depth of 10 feet.

In the mean time it will be necessary to complete the training-wall by raising it a foot or two, and extending to such a point as a study of the circumstances shall show to be necessary.

The timber-work may need protection for some time to come, and further efforts should be made to hasten the accumulation of sand.

The width of the cut in the reef, which is now 150 feet, ought to be made 200 feet, and it would also be beneficial to extend its depth a couple of feet. The action of the current cannot be expected to increase the depth on the reef. This can be done only by artificial means.

The stone line forming a part of the main jetty, has steadily settled for the past three or four years, and it will probably be necessary to raise this line 3 or 4 feet.

These are the points which will need attention for a couple of years, and without such attention the work can hardly be regarded as completed.

All operations at the work were suspended in February, the property stored as well as possible, and a keeper placed in charge.

It may be well to notice here an interesting and unusual phenomenon which occurred on the morning of May 10. Happily, it did no damage of any amount.

About 7 o'clock in the morning, the tide being about 4 feet above low-water, the sea began to rise, and in $2\frac{1}{2}$ minutes it rose 6.8 feet, submerging the work and a great deal of land on the shore which is little above high-water. The wave retreated in a few minutes at a slower rate than it had advanced, falling 5 feet in nine minutes. There were a number of these oscillations during the day, but none so large as the one just described.

The wave was propagated from a center of disturbance on the coast of South America which destroyed Iquique, in Peru, and did a great deal of damage on the adjoining shores. This earthquake took place on the 9th May.

This report is accompanied by a map which shows Wilmington Harbor

at the beginning of the work of improvement, and its present condition. These maps are on the same scale, and are arranged for easy comparison.

The lines of the works are also exhibited, and the position of the reef and the area dredged are also shown.

The commercial statistics of the port of Wilmington are as follows for the year 1876:

There arrived during the year 162 sailing-vessels and 243 steamers.

The imports were 66,879 tons, of which 30,000 tons were railroad plant.

The exports were 20,448 tons.

Three cargoes of wheat were exported to Europe, the first instance of the kind.

Wilmington is in the collection-district of San Diego, which is 100 miles distant.

The amount of revenue collected during the year from merchandise imported at Wilmington was $9,021.21.

The nearest light-house is at Point Firmin, 3 miles distant.

The nearest port is at San Diego, 100 miles distant.

The original estimate for the jetty connecting Rattlesnake and Deadman's Islands was $400,000. The actual cost of the jetty was considerably less than this sum.

The amounts and dates of appropriations for this harbor are as follows, namely:

March 3, 1871	$200,000 00
June 10, 1872	75,000 00
March 3, 1873	150,000 00
March 3, 1875	30,000 00
Total	455,000 00
Expended to June 30, 1877	454 056 58

The estimated amount required to complete the harbor is $100,000, which can be well applied in two years.

A principal reason for the increased expenditure over the original estimate is in the fact that it proved to be impossible to place the entrance at the point where it could have been provided most economically, and where it was originally intended to place it.

The improvement of harbors of this class is best made successful by a study of the actions and tendencies of the currents as they are determined by the constructions which are made to control them.

These actions can seldom be fully understood and their directions recognized in advance, but when recognized it is generally a sound principle to act as far as possible in harmony with them and not in opposition.

Unmistakable indications pointed out the proper position of the entrance which ought to be made, but not until the main jetty was completed.

This change from the original design made it necessary to excavate a good many thousand yards of clay and stone, which were not included in the original design.

In addition, works on the sea are exposed to large contingencies, which can never be fully anticipated.

Money statement.

July 1, 1876, amount available	$40,268 15
July 1, 1877, amount expended during fiscal year	39,324 73
July 1, 1877, amount available	943 42
Amount (estimated) required for completion of existing project	100,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	50,000 00

H H 3.

REMOVAL OF RINCON ROCK, SAN FRANCISCO HARBOR, CALIFORNIA.

At the date of the last annual report Cyrus Palmer, one of the sureties on the bond of the original contractor, was engaged in blasting and removing what remained to be done under the original contract. This contract required a depth of 24 feet to be secured.

An examination of the work was made in July, which showed that outside of a line 100 feet distant from the wharf, within which no blasting was permitted, in accordance with a request of the State harbor commissioners, there remained to be excavated 62 yards, and additional depths from 2¼ feet to a few inches had yet to be attained.

The blasting was the cause of some danger and annoyance to the ships lying at the wharf within 100 or 200 feet of the scene, and probably this was one of the motives which led the harbor commissioners to request that the work be no further prosecuted. They also expressed the opinion that the work was sufficiently advanced to serve the interests of the commerce of the port.

Inasmuch as the rock lay within the jurisdiction of the harbor commissioners, as established by the statutes of the State, and, further, as the commissioners were the proper judges of the necessities of commerce within their jurisdiction, it was deemed proper to accede to their views. Accordingly, with the approval of the Chief of Engineers, the contractor was permitted to leave the work in the condition in which it was at the time of the survey, and payment was made for the proportion of the work actually done.

The original contract called for the excavation of 4,745 cubic yards, of which only 4,357 were actually removed. The price stated in the contract was $43,000. The money actually paid was $39,483.88.

The least depth of water on the rock is 21¾ feet at mean low-water, or about 20 feet at low-water of spring tides.

Money statement.

July 1, 1876, amount available	$24,380 27
July 1, 1877, amount expended during fiscal year	20,157 75
July 1, 1877, amount available	4,222 52

H H 4.

IMPROVEMENT OF SACRAMENTO AND FEATHER RIVERS, CALIFORNIA.

No operations were carried on last year.

The last and only work that was done in these rivers was executed in 1875, under an appropriation of $15,000, made at the preceding session of Congress.

The Sacramento was a navigable channel from its mouth to a point near Chico, something like 300 miles in length. The lower part of the river is embarrassed here and there with bars, which form serious obstructions in the low stages of the water. Some of these bars in former years were washed out to some extent by wing-dams, built by private corporations interested in navigation. Latterly, however, the tonnage of traffic has fallen off in the lower river on account of the competition with railroads, and no single party has been sufficiently interested to make any expenditures in removing bars.

The upper river has a much greater fall than the lower half. It has

a number of rapids alternating with pools of deep water. The principal obstructions to navigation are, however, snags, which are thrown into the river in each succeeding winter in considerable numbers.

During the past season 58 snags were taken out by private parties.

The main traffic on the upper river is in wheat. It is usually brought on barges carrying several hundred tons, which deliver it to vessels in the harbor of San Francisco, or land it at Knight's Landing, from which point it is carried by rail to Vallejo, where it is shipped to foreign ports.

It is estimated that in the year 1876 167,000 tons of wheat were brought out by 17 steamboats.

The country on the banks of the river is extremely fertile, and its production increases from year to year, and is likely to continue to increase for some years to come.

Ten thousand dollars a year will keep the upper river from Knight's Landing to Walsh's Landing or Chico in very good condition as far as snags are concerned.

The Feather River is the largest tributary of the Sacramento. It is navigable for a distance of 40 miles above its mouth to the town of Marysville. One or two light-draught steamers ply on the river between Marysville and San Francisco.

There are a few snags in the river at times, but the main difficulty is in want of depth of the channel in its low stages. Some of these shoals were deepened two years ago. There is no difficulty in obtaining the desired depth at any point. The silt on the bottom is readily moved, but the shoals re-appear at other points. This river is the main outlet for the silt which results from the operations of hydraulic mining. The pressure of this increased quantity of material supplied each year from the mines, and the unimportance of the navigation, are reasons why no extensive system of improvement should be undertaken on this river, and nothing short of a system of improvement can do any good of a permanent character.

The export of wheat by the Feather River is believed to have been about 15,000 tons in 1876.

It is not recommended at present to undertake any work looking to the improvement of the navigation of these rivers, except to remove such snags as form a serious obstruction and danger to navigation, and to remove bars in particular cases where the inconvenience is very great.

Reference has been made in previous reports to the necessity of a thorough examination and survey of the lower parts of the Sacramento and San Joaquin, looking to the improvement of their navigation and to the solution of the physical problems which are forced upon our attention by the reclamation of the deltas of these rivers and the enormous proportions of hydraulic mining.

The considerations which have been stated under these heads have lost none of their force and importance.

Twenty thousand dollars can be well applied in the coming year to such improvements of navigation as have been mentioned and to the beginning of a general examination of these important problems.

An examination of Georgiana Slough, one of the delta arms of the Sacramento, connecting it with the San Joaquin, was made in June, under the instructions of the Department, by Lieut. A. H. Payson, of the Corps of Engineers. His report is appended.

These rivers lie in the collection-district of San Francisco, some statistics of which will be found in the annual report for Oakland Harbor.

The nearest forts and light-houses are those which exist on the waters of San Francisco Bay.

Money statement.

July 1, 1876, amount available	$259 88
July 1, 1877, amount expended during fiscal year	16 63
July 1, 1877, amount available	243 25
Amount that can be profitably expended in fiscal year ending June 30, 1879.	20,000 00

REPORT OF LIEUTENANT A. H. PAYSON, CORPS OF ENGINEERS.

About 25 miles below the city of Sacramento the river of that name divides into Old River and Steamboat Slough, the latter being the branch taken by the main commerce on the river, though the former is a good navigable stream, and has one freight-steamer up and one down it daily. Six miles below its head the Old River throws off a branch called Georgiana Slough; this latter, though making many sharp bends, flows in a general southwesterly direction, parallel to and at an average distance of much less than a mile from the Old River, for about 9 miles from its origin; thence it bends abruptly to the east, runs almost directly away from the Old River, and empties into the Mokelumne, nearly at the junction of the north and south forks of that stream; its waters eventually reach the San Joaquin, through the mouth of the Mokelumne, about 20 miles above the junction of that river with the Sacramento. The slough separates two islands, Andrus and Tyler; the former, long and narrow, is on its right bank, between it and the Old River; the latter, somewhat wider, on its left bank, between it and the North Fork of the Mokelumne.

At the head of the slough on Old River its width is between 100 and 130 feet. The banks on both sides are of a stiff clay, about 4 feet above low-water, and surmounted by a levee from 5 to 6 feet higher. The depth is about 20 feet at low-water in mid-channel, and the banks under water seemingly nearly vertical, soundings of from 10 to 15 feet being found within 5 feet of them. Both banks are nicely timbered in a belt of from 50 to 200 feet in width, of oak, sycamore, walnut, and smaller trees.

About a mile from the head of the slough the levee on Tyler Island ends, and does not again appear, except here and there in slight banks, from 1 to 2 feet high, thrown up merely as a protection against very high tides, but not against floods. On Andrus Island the levee is continuous, and in very good order, throughout the length of the slough.

The stream maintains its general character and depth, though sometimes widening for a short distance to nearly 200 feet, and its banks very gradually becoming lower, until the remarkable oxbow bend, shown in the tracings, is passed, whence its width is permanently increased to at least 200 feet; the banks become only from 1 to 2 feet above low-water and overgrown with tules; the timber disappears, save a few bushes here and there; the banks are shelving and the water shoaler, until the Mokelumne is reached, 2½ miles below the foot of the bend. The entire length of the slough is about 12 miles.

For the first 9 or 9½ miles there can be no possible doubt about there being ample water at all seasons of the year, the only obstructions being snags and overhanging trees; for the last 2½ or 3 miles the snags and trees disappear, and the depth of water becomes the question.

I timed my arrival at the mouth of the slough at extreme low-water of a spring-tide, when the high-water mark of the morning's tide was nearly 4½ feet above the water-level, and sounded out into the Mokelumne, making also six lines of soundings across the stream in the last mile and a half of its course, and found that I could carry out 10 feet in depth for a width of from 40 to 50 feet. As I do not believe that, even in the driest season, the water can be more than from 1½ to 2 feet lower than when I saw it, and as the large freight-boats draw from 6 to 7 feet when loaded, I am quite certain that no trouble from lack of water can occur in the Georgiana Slough as long as it retains its present character.

I made three measurements of the velocity of the current, getting results varying from 1½ to 2 miles per hour, these observations being taken near the middle of the ebb, so as to obtain nearly a maximum.

The current may be said to be almost always down, though probably a very high spring-tide, occurring in an extreme low stage of the rivers, would reverse it—at all events in the lower part of the slough. At the time of my visit the current was sensibly down about 4 miles from the mouth of the slough, at the top of a very high tide.

There are, of course, two tides in the slough, one large, the other small, corresponding to those in the bay, but occurring about six hours later. The ebb of a large spring-tide runs from eight to nine hours, the flood, three or four; for small tides, the dura-

tions of the ebb and flood are about equal. During a course of spring-tides the large high-water rises from 4 to 5 feet, the small from 2 to 3.

The improvement of the slough resolves itself, then, into the removal of snags and overhanging trees. Though a large freight-steamer has been through the slough within the last three months, and trips are sometimes made by boats, for special purposes, as far as Westfall's ranch, 6 miles from its head, still it cannot be considered navigable while steamers only venture in with great reluctance and at much risk; for while the slough is wide and deep enough as it stands, yet, owing to the rapid current, a vessel is likely to be thrown, in passing bends, against one or the other bank, which, in their present condition, would probably cause its loss.

To make it perfectly safe, then, requires the removal, first, of all snags in the channel; second, of all roots of large size projecting from the concave bank in bends; and, third, of all large overhanging trees similarly situated.

For these purposes I submit the following estimate:

Projecting roots in bank	$300 00
For removing wreck of small schooner sunk in channel	200 00
Two rafts of snags interlaced with brush	300 00
200 overhanging trees on concave side of bends	2,000 00
200 snags in channel, at $55 per snag	11,000 00
Total	13,800 00
Add for contingencies	1,200 00
Total	15,000 00

The advantages to be gained in opening Georgiana Slough for navigation should be considered under two heads, viz:

1. The local benefit to the property-owners on the banks.
2. The general advantage to the internal navigation of this part of the State.

On the right bank of the slough is Andrus Island. This is entirely leveed and in a high state of cultivation, the inner portion devoted principally to grain, and the bank bordering on Old River to fruit. Drawing a line through the middle of the island so as to separate the portion whose products would naturally seek the Old River from that bordering on Georgiana Slough, I find that there are about 3,000 acres for which the slough would be the more convenient outlet, apparently; but when we consider that, first, the Old River being the present navigable stream, most of the ranch-owners and cultivators live on its bank; second, that the island, being dry, can be crossed anywhere by a road without trouble; third, that the distance from the slough to Old River is nowhere more than a mile, and in most places much less; and, lastly, that most of the ranches extend entirely across the island, it may be doubted whether the opening of Georgiana Slough would be of any sensible advantage to Andrus Island, or even that, in case it were opened, the products of the island would seek that channel in preference to the present one down the Old River.

Pursing the same course with Tyler Island, I find 4,400 acres of it nearer the slough than the north fork of the Mokelumne, which forms its eastern boundary, and is a navigable stream.

But of this a certain portion near the northern end, say 400 acres, must be deducted, since it can and does at present find a convenient outlet through Old River; and this portion includes nearly all of the island which is at present under cultivation. For the rest, now unreclaimed, Georgiana Slough affords the only practicable channel to a market, since the alternatives are, first, to ferry across the slough and haul to Old River; second, to haul across the low and marshy Tyler Island, for distances varying from 1 to 3 miles, to the north fork of the Mokelumne, both of which may be regarded as practically prohibitive.

The local advantages of the proposed improvement may then be summed up as those to be derived by the owners of land on that half of Tyler Island bordering on the slough from a point 1 mile below its head to its mouth, say 4,000 acres, the reclamation of which it would probably at once render profitable and greatly hasten.

Now, with regard to the part taken by the slough in the internal navigation of the State.

Formerly a line of steamers ran regularly through it between Sacramento and Stockton.

Taken in connection with the Old River and Mokelumne, it forms a cross-cut from the Sacramento to the San Joaquin, and effects between all points on the latter above the mouth of the Mokelumne, and all points on the former above the head of Old River, a saving in distance of about 30 miles—that is to say, it is 30 miles shorter to go from the mouth of the Mokelumne up through Georgiana Slough to Sacramento than by the San Joaquin to its junction with the Sacramento at Collinsville, and thence up the latter stream.

Undoubtedly this would be an advantage, for I am told that there is often a better

market in Sacramento for hay, potatoes, barley, &c., the chief products of this region, than in San Francisco, and that consequently freight, at certain seasons of the year, seeks to go and is sent from points on the San Joaquin and Mokelumne Rivers to the former place. Still, much of this traffic would probably use sailing-vessels, to whom the superior width and convenience of the main rivers would do much to compensate for the increased distance by them; and as, after all, the main market for the products of the land on both rivers will be always in San Francisco, it does not seem to me that the opening of Georgiana Slough, though undoubtedly a convenience much desired by river-men, is at present demanded by the general navigation interests of the State. I append a tracing showing the relative position and course of the Old River, Georgiana Slough, and the Mokelumne, together with the holdings of the property-owners on Andrus and part of Tyler Islands.

Respectfully submitted.

A. H. PAYSON,
First Lieut. of Engineers.

APPENDIX I I.

ANNUAL REPORT OF LIEUTENANT COLONEL C. SEAFORTH STEWART, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
San Francisco, Cal., July 5, 1877.

SIR: I have the honor to transmit herewith annual reports for the year ending June 30, 1877, of the river and harbor improvements in my charge.

I have the honor to be, very respectfully, your obedient servant,

C. SEAFORTH STEWART,
Lieut. Col. of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

I I 1.

IMPROVEMENT OF THE HARBOR AT SAN DIEGO, CALIFORNIA.

The San Diego River formerly emptied into False Bay. Many years since, during a freshet, its course was changed to the southward and its waters poured into the harbor of San Diego. For a long time more or less of the sand and soil brought down by the river has been deposited in this harbor to its great injury. To prevent further damage it has been proposed to turn the river back into False Bay.

The works planned for this purpose consist essentially of an artificial water-way, starting from a point in the bed of the river near the Presidio Hill and thence leading to a slough which empties into False Bay, near the northern extremity of Point Loma peninsula; of the filling in of the old bed where necessary to turn the waters into the artificial channel, and, on the south side of the latter, of a levee about $1\frac{1}{2}$ miles long from the Presidio Hill to Point Loma peninsula, to prevent the water when overflowing the banks of the channel from finding again an outlet across the plain into San Diego Harbor.

In plan the longitudinal axis of the embankment is an arc of a circle whose radius is 11,139 feet, and whose convexity is to the north. The width on top was to be 23 feet, the side slopes $\frac{2}{3}$, the height 6 feet. At the foot of the fore-slope a trench was to be dug, 4 feet wide at bottom, with side slopes of $\frac{2}{1}$, or as steep as the light sandy soil would allow, and to a depth where water should be reached. The trench was to be

filled with stone to the level of the natural surface of the ground. On this stone substructure was to rest the foot of the dry cobble-stone facing of the fore-slope of the levee; the thickness of this facing being for 2,500 feet from the east end of the embankment 3 feet measured horizontally, and but 2 feet for the rest of the way. To the north of the levee a berm was to be left 100 feet wide; then the excavated channel-way, on top 150 feet wide, on the bottom 100 feet; the south slope with a base of 50 feet, the northern vertical, or that taken by the earth. The average depth of channel to be 1.6 feet.

Messrs. Howard Schuyler and George A. Johnston, the contractors for earth and stone work, broke ground on the 5th of June, 1876, and on the 30th of that month, the end of that fiscal year, had built and faced with stone a running length of 350 feet of the eastern end of the levee and had begun the excavation of the channel-way and the construction of the embankment at the west end. It was found that during the previous winter the river had washed away much of the material at the east end of the proposed work, and that the little left was unsuitable for the construction of this part, which was that most exposed to the attacks of the river. Authority was therefore obtained, at the beginning of the present fiscal year, for the contractor, under a special agreement, to take clay from the Presidio Hill and build with it a length of some 2,300 feet of the east end of the levee. Owing to the extra quality of the material used and its additional cost, the width of levee at top, for the length mentioned, or thereabouts, was reduced to 16 feet. The remainder of the embankment, made of the light material taken from the excavation of the channel-way, was kept on top of the full width of 23 feet.

The trench for foot-wall for this eastern portion of the work was, for greater security, dug to a depth of 5.5 feet, with a uniform width at bottom of 4 feet, varying at top from 8 to 17 feet. Thence the depth diminished gradually to 3 feet at the western end.

The entire facing of the fore-slope of the levee was of smooth, hard cobble-stones laid by hand, and the greater part of the foot-wall was made of like material. The whole work contracted for was finished on the 6th of November, 1876, about five months after breaking ground, and nearly two months earlier than the limit set in the contracts.

Judging from my own inspections and from the reports of Lieut. John H. Weeden, the engineer officer in local charge, Messrs. Schuyler & Johnston did the work in the most thorough, satisfactory, and workmanlike manner. This was due to the fact that Mr. Schuyler, an engineer of skill and experience in railroad construction, personally supervised the work.

Owing to the extra quantity of stone required in bad soil to give greater security to the foot of the levee, it was impossible to fence in the works and pay the necessary contingent expenses of the constructions. So far, if reports can be relied on, a fence has not proved a necessity.

Hereafter, should it be thought best to plant the berm with trees, a fence would be required to protect them from the cattle allowed to roam over the plain. To protect the fence from the attacks of irresponsible persons, one or two watchmen would be necessary, and to pay them, annual appropriations would have to be made. During the past winter there have been no floods in the river to test the works. Their value and what may be the cost of yearly repairs can only be ascertained by the experience of future years.

In the past fiscal year 87,261.503 cubic yards of earth have been exca-

vated, forming in position 7,384.64 running feet of levee. The amount of stone procured and put into the foot-wall and facings of this embankment, during the same time, amounted to 13,020.68 cubic yards measured in the work.

The whole length of levee and artificial channel-way, as completed, is reported to be 7,734.64 feet, and the whole amount of earth excavated and used for the embankment, since the breaking ground, is given as 91,628.503 cubic yards; that of stone in place being 13,454.68 cubic yards.

The cost of the works finished has been $79,798.72; the amount appropriated having been $80,000.

This improvement is situated in the collection-district of San Diego, which town is the nearest port of entry.

The nearest light-house is Point Loma light. The nearest fort is that recently begun at Ballast Point, at the entrance to the harbor of San Diego. The amount of revenue collected at this port of entry during the past fiscal year is reported as $5,080.03.

The benefit to commerce and navigation from this work will be that due to the conservation of the only good, landlocked harbor on our Pacific coast, south of San Francisco, so long as the San Diego River shall be kept from emptying therein.

Money statement.

July 1, 1876, amount available	$74,182 49
July 1, 1877, amount expended during fiscal year	73,981 21
July 1, 1877, amount available	201 28

LIST OF PRINCIPAL EXPORTS SHIPPED FROM THE PORT OF SAN DIEGO, CALIFORIA, FROM JULY 1, 1876, TO JUNE 30, 1877, INCLUSIVE.

Honey, in comb, pounds net	686,005
Honey, strained, &c., pounds net	156,185
Bees-wax, pounds net	7,275
Hides, dry and salt, pounds net	120,620
Tallow, pounds net	10,900
Pelts and skins, dry and salt, pounds net	36,019
Fish, pounds net	224,540
Wool, pounds net	1,051,061
Salt, pounds net	158,147
Flour, pounds net	200,000
Leather, pounds net	8,400
Whale oil, barrels	1,029
Potatoes, pounds	8,848
Eggs, dozen	445
Ore, silver, pounds	40,467
Bees, hives	26
Bees, boxes	82
Wheat, pounds	3,498,856

The above is a carefully compiled statement.

J. H. SIMPSON,
Local Agent Pacific Coast Steamship Company.

II 2.

IMPROVEMENT OF SAN JOAQUIN RIVER, CALIFORNIA.

The expenditure of the $20,000 appropriated August 14, 1876, for this work having been authorized in March last, an examination of the river was made in that month.

It is proposed to survey those portions below Stockton where navigation is most impeded so soon as the low stage of water is attained, and, if necessary, contract in the usual manner for the removal of the shoals by dredging.

Money statement.

Amount appropriated by act approved August 14, 1876	$20,000 00
July 1, 1877, amount expended during fiscal year	6 80
July 1, 1877, amount available	19,993 20
Amount (estimated) required for completion of existing project	19,993 20
Amount that can be profitably expended in fiscal year ending June 30, 1879.	19,993 20

APPENDIX J J.

ANNUAL REPORT OF MAJOR JOHN M. WILSON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

UNITED STATES ENGINEER OFFICE,
Portland, Oreg., June 30, 1877.

GENERAL: I have the honor to transmit herewith my annual reports for the fiscal year ending June 30, 1877, upon the works of river-improvement under my charge.

Very respectfully, your obedient servant,

JOHN M. WILSON,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

J J 1.

IMPROVEMENT OF THE LOWER WILLAMETTE AND COLUMBIA RIVERS FROM PORTLAND, OREGON, TO THE SEA.

The difficulties to be overcome in opening the channel for deep-draught vessels through the various bars from Portland to the sea were fully set forth in my annual report for the fiscal year ending June 30, 1876, and the subject of the improvement of this stretch of navigation has been carefully considered by the Board of Engineers of the Pacific coast.

The report of the Board having been submitted to the Chief of Engineers, and approved by him, it is not deemed necessary to again describe the various bars in the Lower Willamette and Columbia Rivers.

OPERATIONS DURING THE FISCAL YEAR.

By the act of Congress approved August 14, 1876, an appropriation of $20,000 was made for this work, which it was determined to expend in excavating channels through the bars at Swan Island, Post-Office Bar, mouth of the Willamette, and Saint Helen's.

The extraordinary freshet of 1876, which reached a height of 28.2 feet above low-water on June 24, 1876, commenced to abate on that day, and on August 11, 1876, the river being still 10 feet above low-water, the work of excavation was commenced with the United States dredge at the bar at the

MOUTH OF THE WILLAMETTE RIVER.

Careful surveys made at this locality show that the fall in the Willamette from the head of Willamette Slough to the mouth of the river, a

distance of $3\frac{3}{4}$ miles, is absolutely nothing at ordinary low-water. The consequence is, that when the Columbia commences to rise the whole volume of the Willamette passes through the slough while the Columbia water runs up the Willamette, a large portion passing down through Coon Island Slough, and a still greater portion down the Willamette Slough.

The bar at the mouth of the Willamette is formed by the Columbia freshets, and the filling this year was greater than usual, being from 3 to 6 feet.

Work was commenced with the dredge on August 11 and continued with various interruptions from breakage, &c., until September 1, during which period a channel 700 feet long, 100 feet wide, and $16\frac{1}{2}$ feet deep at low-water was opened by removing 5,875 cubic yards of sand; no trouble was therefore experienced by vessels on this bar throughout the year.

The dredge was then towed to

POST-OFFICE BAR,

about 3 miles above the mouth of the river and just below the entrance to the Willamette Slough, where work was at once commenced and was continued until October 12. During this period a channel 3,000 feet long, 40 feet wide, and 17 feet deep at low-water was opened by removing 10,935 cubic yards of mud and sand. The cause of this bar, and the proposed plan for removing it, are fully set forth in the report of the Board of Engineers; the filling during the winter and spring had been slight compared with that at the mouth of the Willamette, but was sufficient to require the dredge to work for the period mentioned, and had circumstances permitted, the deep channel would have been made 100 feet wide instead of 40 feet.

The dredge was then towed to

SWAN ISLAND BAR,

$2\frac{1}{2}$ miles below Portland, and operations were continued until November 15, when they were suspended for the season on account of the freshet in the Willamette River. Much delay occurred here from breakage arising from heavy drift-logs which had lodged in and on the bar; the channel was, however, widened and deepened at various points; 4,475 cubic yards of mud, sand, gravel, &c., having been removed from the bar.

On November 16 the dredge was placed in winter quarters, and the crew, with the exception of the engineer and watchman, discharged.

The river fell again early in December, and work could have been carried on during a portion of that month and January, but the freshets at that season rise so suddenly, that it was not deemed advisable to ship a crew and start work for fear it could be continued only for a day or two. In March, 1877, the Willamette at Portland rose to a height of 19 feet above low-water. With the exception of some slight trouble on Swan Island Bar during the extreme low-water in January, no difficulty was experienced in the Willamette River below Portland with any vessel that could cross.

SAINT HELEN'S BAR, COLUMBIA RIVER.

In the last annual report reference was made to a cut that had been dredged through the upper end of Saint Helen's Bar, and the possibility

of maintaining a channel at that locality. Upon the subsidence of the freshet of 1876, it was found that not only had this cut been filled, but that also the main ship-channel at the lower end of the bar hitherto used by deep-draught vessels had been closed, the depth being reduced from about 16 to 13 feet at low-water; the same freshet, however, opened a new channel a few hundred feet below the cut dredged in 1875–'76, at the narrowest portion of the bar, and increased the depth for a width of about 300 feet from about 12 to 16 feet at low-water.

Buoys were placed at this locality, and the channel was used during the fall and winter of 1876–'77; an examination in the spring of 1877 showed that the line of deepest water had shifted slightly during the winter; considerable change is expected from the freshet of 1877, now in progress.

SURVEYS DURING THE YEAR.

In accordance with instructions from the Board of Engineers of the Pacific coast, extensive and elaborate surveys have been made during the year, under my direction, of the Lower Willamette River, the Willamette Slough, the Columbia River, in the vicinity of Saint Helen's, and of Snag Island Bar, above Tongue Point. These surveys include the shore-lines, soundings, volume, velocity, &c., and the results are fully set forth in the interesting report, transmitted herewith, of Assistant Engineer R. A. Habersham, to whom I am indebted for able, energetic, and earnest assistance not only upon this work, but also upon others under my charge.

The survey of Snag Island Bar gave a depth of not less than 15 feet at low-water, with two flood-tides daily of from 6 to 8 feet.

BAR AT THE MOUTH OF THE COLUMBIA.

There is presented with this report a chart of the bar at the mouth of the Columbia River, Oregon, prepared from surveys made under my direction during the summer of 1876; it is hoped that this chart will be published for the benefit of mariners. It will be observed that there is a wide channel over the bar with a depth of not less than 20½ feet at low-water; there are two tides daily, with a rise of from 7 to 9 feet. This bar has, I believe, an undeservedly bad reputation; properly buoyed, I think it no more dangerous than that at Sandy Hook, New York; of course there are occasions when, from violent southwest gales, it becomes furious and breaks clear across, but the occasions are seldom when a vessel cannot cross with safety.

SURVEY OF SAND ISLAND, MOUTH OF COLUMBIA.

The annual survey of Sand Island was made in May, 1877, and showed an erosion of about 200 feet on the weather face and a gain of from 200 to 400 feet on the lee face since the survey of 1876; this island has moved about 1,800 feet, nearly, due north in the last nine years, its superficial area remaining about the same and its shape being slightly changed.

THE UNITED STATES DREDGE.

This dredge has been steadily engaged during the last five years, whenever the freshets would admit, in excavating the channels through the various bars; it is of the Morris & Cumings pattern, and while excellent for mud, the bucket holds with difficulty the very fine sand of

the Columbia River bars; it seldom, if ever, on this work, excavates more than 350 cubic yards per day.

During the coming season it is proposed to continue work as soon as the freshet will admit, dredging the channels through the various bars between Portland and Saint Helen's; this is necessary in order to keep open navigation, the funds available not being sufficient to construct either of the dams recommended by the Board of Engineers; whenever funds are available, the first work to be undertaken should be that of partially closing the Willamette Slough. Surveys will also be continued for the further investigation of the regimen of the Willamette River in the vicinity of Swan Island Bar, and of that of the Columbia at Saint Helen's Bar.

The following information, required by the act of Congress approved June 23, 1866, is respectfully submitted:

The appropriations for this work have been as follows:

Act of June 23, 1866, Lower Willamette	$15,000 00
Act of March 2, 1867, Lower Willamette	30,000 00
Act of July 25, 1868, Lower Willamette	21,000 00
Act of April 10, 1869, (allotted)	13,365 00
Act of July 11, 1870, Lower Willamette	31,000 00
Act of June 10, 1872, Lower Willamette	50,000 00
Act of March 3, 1873, Lower Willamette and Columbia	20,000 00
Act of June 23, 1874, Lower Willamette and Columbia	20,000 00
Act of March 3, 1875, Lower Willamette and Columbia	20,000 00
Act of August 14, 1876, Lower Willamette and Columbia	20,000 00
Total	240,365 00

Of this amount $221,780.46 has been expended to date, building dredge, scows, and dike, and in dredging and surveying bars.

The project now submitted calls for the construction of dams at Swan Island, Willamette Slough, mouth of the Willamette, and Saint Helen's Bar, the estimated cost of which is $298,974; of this amount $150,000 can be profitably expended during the next fiscal year.

COMMERCIAL STATISTICS.

There are two ports of entry on these rivers: Astoria, 12 miles from the mouth of the Columbia, and Portland, 12 miles from the mouth of the Willamette, or about 120 miles from the mouth of the Columbia.

Astoria statistics.

I am indebted to Mr. J. D. Merryman, deputy collector of customs at Astoria, for the following information, showing the commerce of that port from July 1, 1876, to June 1, 1877:

The amount of revenue collected during the period mentioned was $26,378; the value of the imports was $24,315, and of the exports $1,488,929. The number of vessels entering on the coasting trade was 153, with an aggregate tonnage of 176,798 tons, and on foreign trade 27, with an aggregate tonnage of 23,398 tons. The number of vessels clearing on coasting trade was 144, with an aggregate tonnage of 171,089 tons, and on foreign trade 50, with an aggregate tonnage of 41,475 tons.

Portland statistics.

To Mr. S. N. Shurtleff, deputy collector at Portland, Oreg., I am indebted for the following information in reference to the commerce of this city from July 1, 1876, to June 1, 1877:

The amount of revenue collected during the 11 months of the present fiscal year was $125,317.10.

The value of the imports was as follows:

By American vessels	$193,274 00
By foreign vessels	195,202 00
Total	388,476 00

These were divided as follows:

Free commodities	$245,864 00
Dutiable commodities	142,612 00
Total	388,476 00

The value of the exports was as follows:

By American vessels	$248,575 00
By foreign vessels	2,260,584 00
Total	2,509,159 00

The exports were as follows:

Wheat, 1,840,133 bushels, valued at	$1,965,381 00
Flour, 93,126 barrels, valued at	484,521 00
Bran, 174,856 pounds, valued at	1,812 00
Middlings, 48,378 pounds, valued at	1,007 00
Chops, 9,987 pounds, valued at	146 00
Other commodities	56,292 00
Total	2,509,159 00

The number of vessels entering this port was as follows:

Class.	With cargoes.			In ballast.		
	Number.	Tonnage.	Crews.	Number.	Tonnage.	Crews.
Coastwise	109	104,549	3,989			
American vessels, foreign	10	4,223	179	2	1,923	34
Foreign vessels, foreign	14	9,317	237	42	32,949	816
Total	133	118,089	4,405	44	34,872	850

The number of vessels clearing was as follows:

Class.	With cargoes.		
	Number.	Tonnage.	Crews.
Coastwise	70	85,470	3,433
American vessels, foreign	23	12,864	541
Foreign vessels, foreign	60	45,962	1,132
Total	153	144,296	5,106

Recapitulation.

Total amount of revenue collected at Portland	$125,317
Value of the imports	388,476
Value of the exports	2,509,159

One hundred and seventy-seven vessels, with an aggregate tonnage of 152,961 tons, and crews amounting to 5,255 entered, and 153 vessels, with an aggregate tonnage of 144,296, and crews amounting to 5,106 cleared. The value of the exports exceeded that of the imports by $2,120,683.

GENERAL SHIPPING STATISTICS.

From the report of D. C. Ireland, clerk of the board of pilot commissioners of Oregon, submitted in the report of that board to the legislative assembly at its ninth regular session in 1876, I quote the following:

During the period of 2 years from the date of this report, September 1, 1874, to September 1, 1876, (at which time 23 vessels, with an aggregate tonnage of 13,382 tons, were in port,) 457 vessels have arrived from sea with an aggregate tonnage of 340,907 tons, and the various fleets that have departed for sea within this period have carried an aggregate of 310,961 tons of Oregon's products, embracing wheat, flour, fish, fruits, &c., valued at $11,845,590.27.

This very interesting report gives detailed statements showing the name, tonnage, draught, and value of cargo of each vessel crossing the Columbia River Bar, during the period named, and shows plainly the extensive and growing commerce of this magnificent section of the country. Attention is invited to the fact that on April 21, 1876, the ship Samuel Watts crossed the Columbia River Bar, going to sea, drawing 23½ feet water and having a cargo of 2,034 tons of wheat.

The following table, prepared by Mr. D. C. Ireland, clerk of the board of pilot commissioners, shows the export of breadstuffs from the Columbia River to all ports, by seasons, from 1868 to 1877, each season is from September 1 of one year to August 31 of the next.

Table showing the exports of breadstuffs from the Columbia River to all ports, by seasons, from 1868 to 1877.

	Season, 1868–1869.	Season, 1869–1870.	Season, 1870–1871.	Season, 1871–1872.
Number of centals of wheat exported	69, 416	67, 489	238, 198	506, 373
Number of barrels of flour exported	107, 671	182, 998	195, 624	167, 908
Total number of bushels* of wheat represented in exports of wheat and flour	600, 212	935, 972	1, 277, 304	1, 599, 541
Total value of wheat and flour exported	$589, 812	$1 059, 522	$1, 546, 947	$2, 125, 352

	Season, 1872–1873.	Season, 1873–1874.	Season, 1874–1875.	Season, 1875–1876.	Season, 1876–1877.
Number of centals of wheat exported	664, 359	1, 394, 310	1, 402, 871	1, 953, 018	1, 481, 790
Number of barrels of flour exported	145, 293	230, 211	255, 868	230, 974	195, 785
Total number* of bushels of wheat represented in exports of wheat and flour	1, 761, 083	3, 359, 799	3, 489, 525	4, 294, 413	3, 350, 682
Total value of wheat and flour exported	$1 747, 124	$4, 037, 093	$3, 000, 500	$5, 769, 240	$3, 759, 170

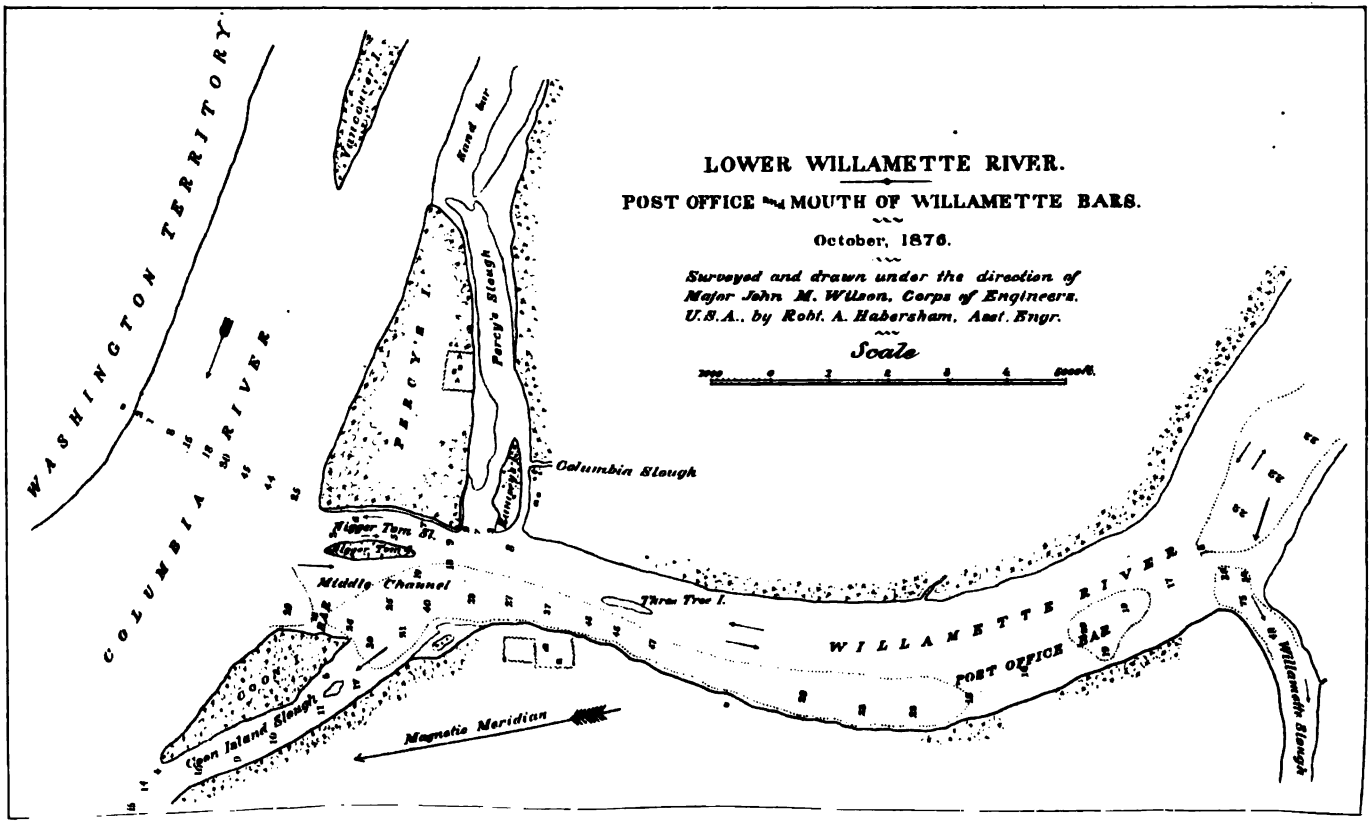
*Centals, reduced to bushels, and in reducing barrels of flour to wheat 4½ bushels is estimated to make one barrel of flour. The season of 1876–'77 not yet being closed the estimate is approximate.

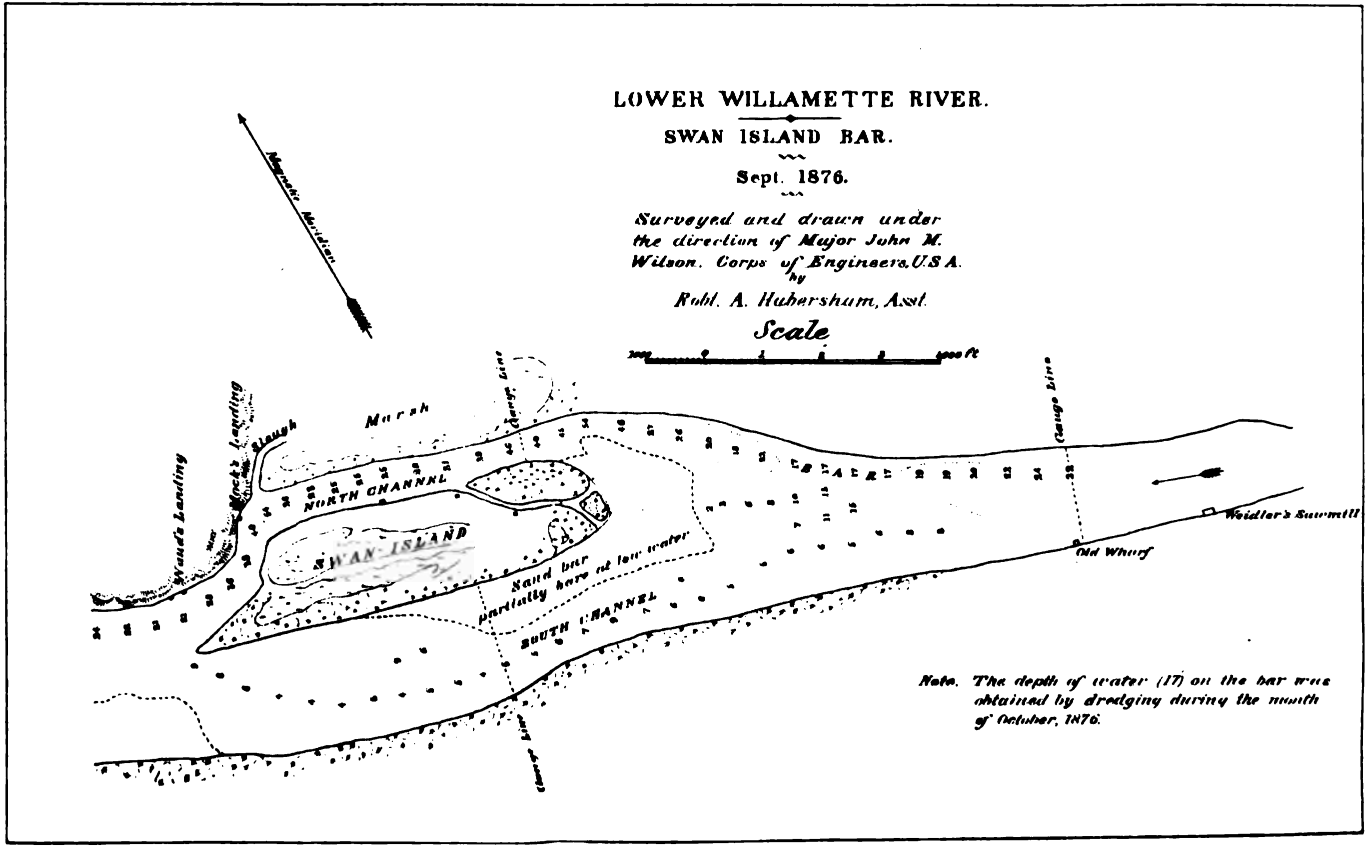
There are two light-houses and two works of defense at the mouth of the Columbia River.

Abstracts of proposals and contracts, a statement of funds, the report of Assistant Engineer R. A. Habersham, and charts of the bars at the mouth of the Columbia, Saint Helen's, the mouth of the Willamette, Post-Office Bar, and Swan Island, are transmitted herewith.

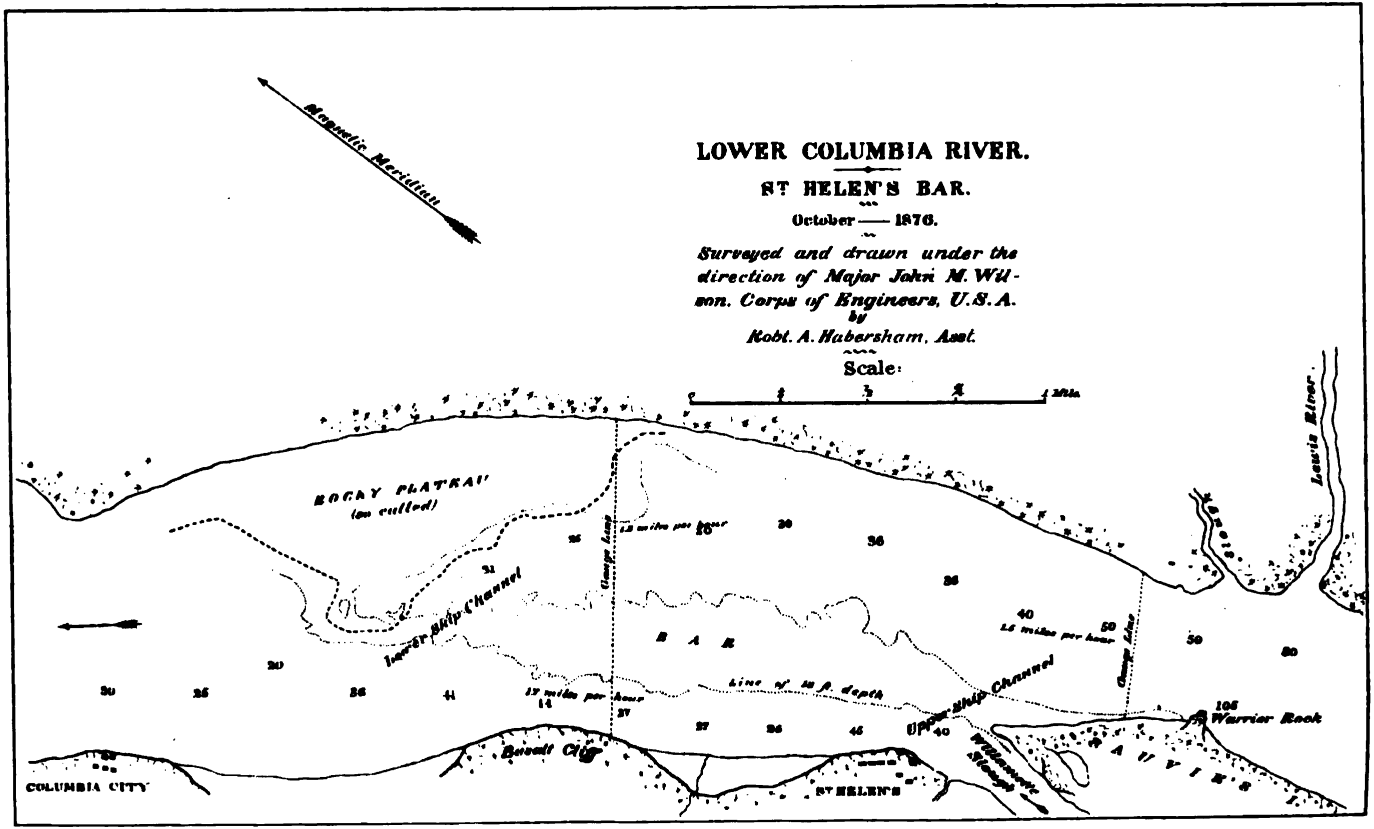
Money statement.

July 1, 1876, amount available	$9, 093 24
Amount appropriated by act approved August 14, 1876	20, 000 00
	29, 093 24
July 1, 1877, amount expended during fiscal year	10, 508 70
July 1, 1877, amount available	18, 584 54
Amount (estimated) required for completion of existing project	298, 974 00
Amount that can be profitably expended in fiscal year ending June 30, 1879	150, 000 00


LOWER WILLAMETTE RIVER.
POST OFFICE and MOUTH OF WILLAMETTE BARS.
October, 1876.
Surveyed and drawn under the direction of
Major John M. Wilson, Corps of Engineers,
U.S.A., by Robt. A. Habersham, Asst. Engr.
Scale
WASHINGTON TERRITORY
COLUMBIA RIVER
Vancouver I.
Sand bar
PERCY'S I.
Percy's Slough
Columbia Slough
Nigger Tom Sl.
Middle Channel
BAR
Three Tree I.
WILLAMETTE RIVER
POST OFFICE BAR
Coon Island Slough
Magnetic Meridian
Willamette Slough



LOWER WILLAMETTE RIVER.
SWAN ISLAND BAR.
Sept. 1876.
Surveyed and drawn under the direction of Major John M. Wilson, Corps of Engineers, U.S.A. by Robt. A. Habersham, Asst.
Scale
Magnetic Meridian
Waud's Landing
Mock's Landing
Slough
Marsh
NORTH CHANNEL
SWAN ISLAND
Sand bar partially bare at low water
SOUTH CHANNEL
Gauge Line
Gauge Line
Gauge Line
Old Wharf
Weidler's Sawmill
Note. The depth of water (17) on the bar was obtained by dredging during the month of October, 1876.



LOWER COLUMBIA RIVER.
ST HELEN'S BAR.
October —— 1876.
Surveyed and drawn under the direction of Major John M. Wilson, Corps of Engineers, U.S.A. by Robt. A. Habersham, Asst.
Scale:
1 Mile
Magnetic Meridian
ROCKY PLATEAU (so called)
Lower Ship Channel
Upper Ship Channel
BAR
Gauge Line
Line of 18 ft. depth
17 miles per hour
14 miles per hour
Lewis River
Slough
Willamette Slough
Warrior Rock
Basalt Cliff
COLUMBIA CITY
ST HELEN'S

REPORT OF MR. R. A. HABERSHAM, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Portland, Oreg., June 8, 1877.

SIR: I have the honor to submit the following report of my surveys on the Lower Willamette and Columbia Rivers, made in accordance with your instructions, during the months of September, October, and November, 1876, and April, 1877, with maps and sections of the work, which consisted of surveys of the shore-lines of the Willamette, and included islands from Portland to its mouth, and of the so-called Rocky Plateau on Saint Helen's Bar, Lower Columbia, including soundings, gaugings, and borings of the Columbia and Willamette Rivers and sloughs, at fifteen different points hereafter to be enumerated, and determination of the high and low water profiles of the two rivers between Portland and Saint Helen's.

The sextant and transit were used to measure angles, and the latter instrument also in measuring distances, being furnished with two parallel horizontal hairs, by means of which the distances were read on a graduated rod to which was attached a target with a vernier reading to tenths and hundredths of a foot. This method of making measurements in ordinary geodetic work is free from the defects attending the use of the chain or tape-line, such as variation in length caused by change of temperature, liability to break, errors from rough ground, and in counting chains, gives at one operation the distance between two points, without the delay of measuring the intervening space, dispenses with the services of two chainmen, and in many cases of one or more axmen, and is consequently reliable, rapid, and economical. Its accuracy may be seen by the close approximation of the following measurements, verified by a metallic tape-line:

	Feet.
Distance measured with metallic tape	300.00
Distance ascertained by graduated rod read to hundredths	299.98
Distance ascertained by graduated rod read to hundredths	300.01
Distance ascertained by graduated rod read to hundredths	299.99
Distance ascertained by graduated rod read to hundredths	299.97
And again:	
Distance measured with metallic tape	1,644.60
Distance by graduated rod read to tenths	1,644.00

This method is much used by French and German engineers and surveyors. Where the ground has an inclination along the line measured of more than 10°, a correction is applied to the sights to obtain the true distance.

BORING.

Gas-pipe, one inch in diameter, in sections 10 feet long, screwed on successively as required, was used in this part of the work. When, as was sometimes the case, hard bottom was encountered, a steel drill was attached. The instrument was worked down by hand, the rod being too slender to stand the blow of a hammer without bending, and a larger pipe meeting too much resistance to admit of its being forced down without machinery.

While boring, the upper end of the pipe was left open to allow the material from the bottom to enter. As soon as the drilled depth (generally 21 feet below lowest water-level) was reached the pipe was closed with a cork, then withdrawn, and its contents taken out. The specimens thus obtained, with others from the shore at various points, labeled, are in your possession. Three kinds of material appear: sand of different degrees of fineness from the bed of the Willamette River and Slough and Saint Helen's Bar; gravel also from Saint Helen's Bar, and clay from the banks at several points where gaugings were made. The gravel was obtained from the so-called Rocky Plateau, a map of which accompanies this report, and is identical in kind with that composing the gravel bars of the Upper Columbia, containing fragments of granite, gneiss, quartz, agate, basalt, &c.

The "plateau" of gravel covers an area of 7,200 by 1,800 feet to a depth of from 2 to 6 feet, resting on a bed of hard material, the exact nature of which could not be determined without boring apparatus specially adapted to this work. It resisted the drill worked by hand, but did not feel like solid rock; rather like cobble-stones and shingle in this particular; also resembling the bars above the Dalles. I consider the great width of the river at this point (5,000 feet, or 50 per cent. greater than the average) as an indication that there is rock in position at no great depth below the surface of the gravel, because, the left side of the channel being walled in by a vertical basalt cliff 200 feet high, the natural effect of the current during freshets would be to cut out a narrow and deep channel were the bottom formed of soft material, as at Warrior Rock, 2 miles above, where the channel is from 50 to 105 feet deep and only 2,000 feet wide.

We know that the basaltic-rock formation common to this section of the Pacific coast underlies the bed of the Columbia throughout at various depths, also that it is not far from the surface in this locality, as it crops out at several places near Saint Helen's. The depth of water on the plateau varies from 2 to 18 feet. The velocity of current is from 1 to 1¼ miles per hour during the low stage, sufficient to carry the small pebbles with which the botton is covered, so that the surface is continually changing shape, the two bars near the lower end moving steadily down stream, deepening the water at this end of the bar, and thus increasing the difficulty of keeping open the ship-channel at the upper end. This constant change in the form of the bottom made it useless to take soundings at the usual short intervals.

Saint Helen's Bar is 2 miles long, crossing the river diagonally from the foot of Sawvie's Island to a point nearly opposite Columbia City, a landing situated 1¼ miles below the village of Saint Helen's. The east bank of the river from opposite Warrior Rock to the lower end of the bar is low, from 5 to 10 feet above low-water, and is composed principally of sand, with occasional veins of clay. It has no stability, and yielding each year to the floods, widens the channel, lessening the depth of water on the bar, and hastening the necessity for improvements at this point.

In the bed of the Willamette, at all points where I made borings, I found only sand to a depth of nowhere less than 21 feet below lowest-water mark. In some places the drill entered 30 feet. Occasional layers of gravel from 1 to 2 inches thick, not compact enough to impede the progress of the drill to any extent, were encountered. I found no hard bottom at any point except on the "Rocky Plateau."

GAUGING.

The apparatus selected was substantially the same as that used by General Ellis in gauging the Connecticut River. It consisted of two floats, surface and subsurface, made of tin; the former a double-convex disk, water-tight, and having a socket in the center for holding a small flag or other signal; the latter an annulus, weighted with lead, to be submerged to any required depth, the two connected by a copper wire .036 of an inch in diameter, of a length varying with the depth of water. A full description of the apparatus is given in the report of the Chief of Engineers for the year 1875, vol. 2, p. 306.

The points selected for gauging were generally (always, when practicable) about the center of a reach, the width, depth, and general direction of which were sufficiently uniform to insure a steady flow of the current. The operation was performed in the following manner:

Having first measured the distance from shore to shore on a line at right angles to the general direction of the current, and fixed solid stakes on the edge of the water on each side, and range-stakes, easily seen from any point on the gauge-line, on shore, 100 feet were measured out into the stream, on the gauge-line, with a line, the distance marked by a small anchor with buoy attached, and the depth measured.

Two boats were then anchored, one above, the other below the gauge-line, at the center of the section, or 50 feet from shore, and connected by a non-elastic cord, on which were tags 50 feet apart, this distance being maintained by one oarsman in the lower boat pulling gently down stream, keeping the line taut. The floats, the wire having been adjusted so as to give the required depth to the lower, were then dropped into the stream above the bow of the upper boat, to enable them to attain the full velocity of the current before reaching the upper tag, and allowed to drift down stream, the moment of passing the two tags being noted by an observer in each boat. This operation was repeated without changing the position of the boats until a sufficient number of observations had been taken at various depths to give a close average of the velocity of the volume of water passing through the section at the time of measurement. Another section of equal length was then measured and its velocity ascertained by the same process, and so on until the entire river had been measured; the sum of the volumes of all the sections giving the entire discharge of the river.

In some cases the width of the channel, as measured by sections, did not correspond with that previously ascertained, known to be correct. The discrepancy was found to be due to the necessary tightening of the line in measuring, pulling the boats out of position, and was corrected by distributing the difference among the sections in proportion to the depth of water. In such cases the measurement by sections was always less than the first, and the amount of difference varied with the depth.

Where the channel was narrow and the bottom irregular, the depths and velocities were taken at intervals of 50 feet or less. The depths measured while gauging were corrected from an hourly record of the rise and fall of the tide, kept for that purpose.

At some points near the mouth of the Willamette River and in the Willamette Slough, where the current is controlled to a great extent, if not entirely, by the tides of the Columbia, the flow was so variable as to make it impossible to make a connected measurement of the volume discharged, and I was forced to mark the sections on the gauge-line by small buoys anchored, and take the velocities every hour for a day or more, in order to ascertain the greatest uniform flow. Uncertainty as to the continu-

ance of fine weather, necessary for this kind of work, decided me to adopt this plan instead of waiting for more favorable tides. The season was far advanced, and the winter rains liable to commence at any time, raising the water and bringing down quantities of drift-wood, the former defeating my principal object, which was to gauge the rivers at the various points selected during the same stage of water, while the latter would have made it dangerous, if not impossible, to work at all in boats.

The operations above described are slow and tedious, and subject to many interruptions, such as up-stream winds and the regular changes in the direction of the tides, necessitating a suspension of the work at times, drift-wood carrying away anchors, or floats, waves from passing steamers, &c. But the plan of dividing the channel into sections, and ascertaining, by careful measurement, the volume passing through each, is, upon the whole, the least liable to undetected error.

The questions which belong to this subject have been fully discussed in the report above referred to, in which the various systems and methods in use for gauging streams have been minutely explained, and their respective advantage and defects compared, and I can add little except in the particular of experience in the working of the double-float method. During the last fall I made gaugings at 13 different points, requiring over 1,000 current-measurements, at depths of from 2 to 30 feet, and found that I could determine the speed of a current so slow as to be almost imperceptible to the eye, as, for instance, of 5 feet per minute, or 1 mile in 17½ hours, with almost absolute accuracy; repeated observations at the same point giving within 1 per cent. of the same result. Of course such accuracy can only be expected under the most favorable conditions, such as a smooth channel of uniform area and cross-sections, calm weather, and steady flow of the tide. But the results obtained demonstrate the capability of the apparatus. Its greatest defect is that the surface-float is liable to be retarded or accelerated by waves or wind, affecting the speed of the lower float so much that reliable results can only be obtained when the water is smooth and the weather calm. In case of error, the existence of which will be shown by discrepancies between results of different measurements of the same volume, the cause can be traced, and, if not removable, allowed for.

The gaugings were made during the low stage, the water ranging from 3 to 4½ feet above zero, and the current being slow and irregular. The results are shown in the following table:

Willamette River, one-fourth of a mile below the northern boundary of Portland: discharge in cubic feet, per minute ....(1)	786,478
Opposite Swan Island, through the south channel....(2)	530,984
And through the north channel....(3)	284,531
Through both channels....	815,515
Deducting the volume due to rise in the river, as shown on the section-sheets annexed....	24,042
Leaves....	791,473

A difference of 4,995; due principally to the increase of velocity attending the greater height of water, which cannot be stated accurately without more complete current-measurements than I could make. Six weeks later, the water having risen to a height of 6.2 feet above zero, I found the discharge to be—

At (1)....	3,095,400
At (2)....	1,802,470
At (3)....	1,369,138

The increased volume being due almost wholly to accelerated velocity.

During the first week in April last I made additional current-measurements at Swan Island, the water at that time ranging between 10.5 feet and 8.5 feet above zero at Portland.

On the 17th of March the Willamette had been swollen by a freshet, the gauge at Portland indicating a height of 19 feet above zero or low-water mark. From that date it fell at the rate of 1.2 feet per day, until, on the morning of the 24th, having reached 9.5 feet, it commenced rising again, reaching 13 feet on the 26th and 14 feet on the 29th, when the water again commenced to fall slowly at a rate of less than 1 foot per day.

During this high stage, the water at Vancouver, on the Columbia, four miles above the mouth of the Willamette, reached the height of 12.9 feet above low-water, while the gauge at the head of the Willamette Falls, 12 miles above Portland, showed a steady fall. The water of the Willamette was clear, almost entirely free from drift, and with no perceptible tidal changes. It is plain, therefore, that the high-water which prevailed on the Lower Willamette when these measurements were made was due to the rise in the Columbia.

I commenced in the north channel at Swan Island, 200 feet below the Old Wharf shown on the map of my surveys last fall, marked "Lower Willamette, Sheet No. 1." The depths and velocities of the river at this point are extremely uniform, as you will see from the annexed section-sheets. Measurements to ascertain the velocities at different depths, taken in the center of the channel, the water being 35 feet deep, gave the following results:

At 3 feet mean of 6 measurements, 75.9 feet per minute.
At 18 feet mean of 6 measurements, 75.0 feet per minute.
At 30 feet mean of 6 measurements, 65.9 feet per minute.

The danger of the lower float becoming entangled among snags on the bottom deterred me from attempting to measure the current at a greater depth than 30 feet. At this depth the combined pressure of the water and atmosphere flattened the convex side of the lower float, giving it the shape of an imperfect hexagon. This did not, of course, affect its buoyancy.

On April 4 simultaneous measurements of the two channels being impracticable, in the necessary absence of my assistant, the volume in the south channel was measured accurately and the north approximately, the volume in the latter being obtained by the formula $v \times 83 = v^1$ in which v represents the surface velocity at the centre and v' the mean velocity of the entire volume. Of course the result thus found was only approximate. It is seen, however, to accord very nearly with those obtained in the usual way. During this day the water fell 0.2 foot.

On the 5th and 6th the two channels were measured simultaneously by two parties under the charge of myself and an assistant respectively. The current was measured at intervals of about 100 feet from 3 to 6 times at each point, the cross-sections having been previously taken by careful soundings, and the distances marked by buoys. A strong breeze from the northwest on the morning of the 7th prevented a fourth measurement of the south channel, which is exposed and rough in windy weather. The north channel is protected by the promontory back of Wand's Landing.

The volumes and velocities from the 4th to the 7th of April, inclusive, were found to be as follows: (See section-sheets A and B.)

	Height of water above zero.	Mean velocity per minute.	Discharge per minute.
	Feet.	*Feet.*	*Cubic feet.*
April 4, 1877, north channel	10¼	63.75	1,347,802
April 4, 1877, south channel	10¼	48.29	1,223,167
April 5, 1877, north channel	9 6/10	63.43	1,311,965
April 5, 1877, south channel	9 6/10	45.75	1,076,308
April 6, 1877, north channel	9	59.64	1,201,891
April 6, 1877, south channel	9	46.67	1,027,366
April 7, 1877, north channel	8¼	57.68	1,142,004

The weather was generally good, and the water smooth during the progress of the work. On the 5th, however, an up-stream wind made the water in the south channel so rough as to affect the speed of the float considerably, the waves causing a bobbing motion, or rather a succession of stops and plunges. Experiments with a wooden float, loaded to sink just below the surface of the water, and started at the same moment with the tin float, showed that the latter lost from 5 to 10 per cent. of the speed of the current when the waves averaged from 2 to 3 inches in height, and a much greater percentage when the water was at all rough; and in the table of results above given it is seen that on the 5th the mean velocity was less in the south and greater in the north channel than the general ratio of decrease shown by the above table. It appears, therefore, that the effect upon the south channel of an up-stream wind is not only to retard the float, and thereby give an observed velocity lower than the actual, but also by backing up the water to lower the actual velocity and reduce the volume, causing a corresponding increase in the north channel, which is, as above stated, protected from northerly winds, and gains in volume and velocity what the other loses.

The general result shows:

1st. That the mean velocity at a high stage of the river is greater in the north than in the south channel.

2d. That while the mean velocities in both channels decrease as the river abates, the rate of decrease is greater in the north than in the south channel, and it follows that at a certain lower stage they will be equal.

My measurements, made during the lowest stage last fall, showed the south channel

to be the more rapid of the two. It will be remembered that some dredging was done through the bar at the head of the north channel after the relative velocities were determined in September and before the rise of October 24, the time at which the velocity in the north channel was found to have increased so much. Assuming, as is probable, that the greater velocity found in the south channel during low water was in part due to the existence of this bar, and consequently that its removal in part before the occurrence of the October freshet contributed to the excess of velocity found in the north channel during that freshet, the ratio of velocities in the two channels during the coming low-water stage (should the cut now again filled with sedimentary deposit be dredged) will be different from that found last year at the same stage, the south losing in proportion as the north gains.

Should you decide to make further examinations of the current and general conditions of the Lower Willamette and Columbia Rivers during the approaching low-water stage, I would suggest that at all points where there are two channels the current-measurements be made in both simultaneously. The relative velocities thus obtained may be accepted as absolutely correct.

Willamette River, half a mile above the head of Sawvie's Island, was.....(4)	739,514
Allowing for difference of height of water, and consequently of velocity as shown on section-sheet, the volume discharged would be..................	794,013
Willamette Slough, quarter of a mile below its head...........................(5)	950,235
And one mile lower down ....(6)	1,040,255

The measurement at (5) was made during the first and at (6) during the last half of ebb-tide. The difference in volume is partly due to the great acceleration in the rate of flow which always occurs in the slough during the last quarter of ebb, for reasons which I will explain under the head of "Velocity of current."

Columbia River, just above Saint Helen's Bar, (7)................................	9,163,805
And just below the bar, (8)...	10,859,446
Deducting from the latter the volume passing through Willamette Slough, which enters the Columbia a short distance above, in round numbers...	1,000,000
Leaving for (8)	9,859,446

Being a difference of about 7 per cent. between the results found above and below the bar. I consider the latter to be the most accurate, the work having been done in perfectly calm weather, which was not the case with the former.

Willamette River, 1,000 feet above Three-Tree Island, during spring tides, at three-quarters ebb, (9)	392,033
And at the same point at three-quarters flood....................................	548,846

Showing an excess in the volume carried by the flood-tide over that of the ebb of 156,813 cubic feet per minute, about equal to the excess of the volume of the Willamette Slough over that of the river proper as shown above.

Mouth of Willamette.

Coon Island Slough, (10)...	234,125

This was measured during neap-tides, and includes the entire volume of the Willamette, there being no current through middle channel and Nigger Tom Slough at that stage.

Middle Channel during spring tides, (11)	309,453

Very little water then passing through Coon Island Slough.

Nigger Tom Slough.—Here I made several attempts to ascertain the volume, but with no result. The current was scarcely perceptible, and so variable that at no time during the low stage could I find the water flowing in the same direction on both sides of the channel.

Columbia Slough discharges during the spring tides..............................	23,200

On the 22d of November, the water having risen 6 feet in consequence of heavy rains in the Willamette Valley, I returned to the mouth of the river and measured the velocity of the current in the three channels, from which, with the cross-sections previously taken, I obtained the following results:

Coon Island Slough, 10 feet above low-water mark, velocity of current 120 feet per minute; discharge in cubic feet per minute	721,728
Middle Channel, velocity 174 feet per minute, discharge..........................	3,304,608
Nigger Tom Slough, velocity 160 feet per minute, discharge....................	640,000

Making in all 4,666,336 cubic feet of water per minute discharged through the three mouths of the Willamette at the existing stage of water, the tide-gauge at Portland indicating 11.5 feet above zero, while a still larger volume passed through the Willamette Slough at that time.

You will see from the above statement of the results obtained by gauging that the volume of water passing through the Willamette Slough during the low stage of the river is greater than that brought down by the river proper, and that the amount of this excess is about equal, allowing for error in measurement, to that of the flood-tide over the ebb from the Columbia, as shown by the gauging made just above Three-Tree Island; from which it is apparent that during the low-stage a volume of from 150,000 to 170,000 cubic feet per minute from the Columbia enters the mouth of the Willamette during flood-tide, and runs out through the Willamette Slough, re-entering the Columbia at Saint Helen's.

In fact, at that stage of the water the Willamette between its mouth and the head of Sauvie's Island is nothing more than an arm of the Columbia, and upon old charts made 20 years ago, the Willamette Slough is called the Lower Willamette, showing that it has, ever since the country was settled, been known as the principal channel of the river in this locality. I am satisfied, therefore, that any plan for the improvement of Post-Office and mouth of Willamette Bars, in which the erosive force of the current is to be utilized, should include the closing, in part at least, of the Willamette Slough.

DEPTH OF WATER.

During the lowest stage indicated on the gauge at Portland by zero, the depth along the channel, excluding Swan Island, Post-Office, and mouth of Willamette Bars, (where a constant depth of 17 feet is maintained by dredging) varies as follows:

From the northern limit of the city to the head of Swan Island, in the north channel, from 20 to 25 feet; and through the south channel from 5 to 7 feet.

Through the north channel to the foot of Swan Island, from 20 to 54 feet. Thence to Saint John's from 20 to 32 feet, except for a distance of about 400 feet at a point ½ a mile above Saint John's, on the west side of the channel, where there is a bar on which only 18 feet is found at lowest water. From what I can learn the river is gradually shoaling here, and may require attention within a few years.

From Saint John's to the mouth of the river the depth is from 20 to 47 feet.

At the head of Sauvie's Island, just within the Willamette Slough, I found a pool 75 feet deep and about 50 feet across its deepest part. This pool is caused by the scour resulting from the sudden change of direction which the current of the Willamette takes on striking the head of Sauvie's Island, where the bank is nearly vertical from 18 to 20 feet high, and formed of tough clay; 1,500 feet lower down the depth diminishes to 24 feet.

The above are the depths at low tide during the lowest stage of the river, which occurs only at intervals of several years, at the end of unusually long dry seasons. Generally the gradual abatement of the water, which continues through the summer, is checked by the early winter rains at a height of 2 or 3 feet above zero. The lowest point reached during the present fiscal year, so far, 1.2 feet above zero, occurred on December 23, 1876.

VELOCITY OF CURRENT.

The general velocity of the current in the Lower Willamette during the low stage is from 20 to 30 feet per minute, or from one-fourth to one-third of a mile per hour, and when at 6 to 8 feet above zero, from three-fourths to 1¼ miles per hour.

The current through the Willamette Slough during the low stage runs at from seven-tenths to nine-tenths of a mile per hour.

Through the mouths of the Willamette, during the low stage, it is very variable, depending on the winds and tides from the Lower Columbia, never during the low stage exceeding 55 feet per minute, or six-tenths of a mile per hour.

In the Willamette Slough the current is nearly uniform, varying from 60 to 80 feet per minute.

The depth varies with the stage of tide, but the current flows outward at all times. This is due to the following conditions:

The fall of the river from the head of Sauvie's Island to Saint Helen's, at low water, is 1.2 feet. The height of the tidal wave is also 1.2 feet during neap tides, and during spring tides from 2 to 3 feet. The distance between the two points by the slough is 23¼ miles, and by the mouth of the Willamette only 18¼ miles. By the latter route, therefore, the shorter by 5 miles, the channel being from 3,000 to 4,000 feet wide, the tide reaches the head of Sauvie's Island much sooner than by the former, which is narrow and crooked and runs out through the slough, maintaining its ascendency with the aid of the current of the Willamette, all of which flows through the slough, as I have shown above.

The velocity of the current of the Columbia River at Saint Helen's Bar was from 39 to 158 feet per minute, or from 0.45 to 1.7 miles per hour, during the low stage, the greater velocity being just below the bar.

INCLINATION.

I ran a line of levels from Portland down the west shore of the Willamette to its mouth, and thence along the east bank of Sauvie's Island to Saint Helen's, for the purpose of determining the comparative elevations of the high and low water marks at the extreme and intermediate points of the line. The high-water profile, representing the freshet in the Columbia of June, 1876, the highest on record, is as follows:

Calling zero of the flood-gauge at the foot of Yamhill street, Portland, 100.000, the elevation of high water at Portland, due to back-water from the Columbia—

June 24, was	128.200
At mouth of the Willamette	127.999
At Willow Bar, Columbia River	127.387
And at Saint Helen's	126.982
Total fall from Portland to Saint Helen's	1.218

During low-water, the flood-gauge at Portland reading 3.0, the following are the elevations at different points, ascertained by means of tide-gauges graduated to feet and tenths of a foot, their bases or zeros being connected by my line of levels:

At Portland	103 000
At head of Willamette Slough	102.200
At mouth of Willamette River	102.200
At Saint Helen's	101.500

During intermediate stages of the Willamette the fall is much greater than during either high or low water, as shown by the heights of the surface of water at the following points on the 22d November:

At Portland	111.50
At head of Willamette Slough	109.94
At mouth of Willamette River	109.80

I think it probable that the difference of 0.201 foot in the heights of the freshet-marks at Portland and at the mouth of the Willamette, which appears above, is due to my having disregarded the correction for the curve of true level, a portion of the line between these two points having been run over a mountain road where I could not equalize the sights, the length of fore sights being in several instances considerably greater than the back sights, causing the observed level, or line of sight, which is a tangent, to deviate so much from the true level curve as to make a difference appear where none exists. The high-water in the Lower Willamette is due solely to the snow-flood of the Columbia, and, as no current is perceptible during its continuance, I am satisfied there is no fall.

DISTANCES.

From Portland to the head of Willamette Slough, 9¼ miles; thence to the mouth of the Willamette, 2¾ miles; thence to Willow Bar, 6 miles; thence to Saint Helen's, 9 miles; the distance from Portland to Saint Helen's, via the Willamette Slough, being 32¼ miles.

OTHER ITEMS.

The ridge between the Lower Willamette and Columbia terminates abruptly in a rounded spur 200 feet high, 1¼ miles below Saint John's, as shown on the map.

During the June floods the flat lands along the banks of the two rivers, including almost the whole of Sauvie's Island, are overflowed to a depth of from 10 to 20 feet. The seasons at which these floods occur render the bottom-lands almost valueless except for pasturage.

The lower end of Coon Island is being rapidly worn away by the current of the Columbia River, which washes the east side of the island, carrying the eroded material around into the slough, formerly a ship-channel, but now shoaling rapidly at its mouth.

Three-Tree Island, 1 mile above the mouth of the Willamette, is also yielding to the force of the winter floods of the Willamette, and there will probably be very little of it left above the low-water line should any considerable freshet occur during the coming winter. Its highest point is now about 6 feet above extreme low-water mark.

Percy's Slough has no current at low-water, being closed by a sand-bar, which has formed a short distance above the remains of the pile-dam built three years ago. At higher stages, the direction of the current depends upon the relative heights of water in the two rivers. Columbia Slough heads near the mouth of Sandy River, which enters into the Columbia 20 miles above the mouth of the Willamette. Its general direction is parallel to that of the Columbia. At its mouth, at low-water, it is 60 feet wide and 6 feet deep; its width and depth throughout its length vary considerably. When clear of drift and other obstructions, it is navigable for small steamboats from its mouth to Love's bridge, a distance of about five miles; it carries the water of several small

brooks from the northern slope of the ridge between the Columbia and Willamette and runs through a level meadow country, interspersed with numerous lakes and sloughs, overflowed annually by the summer flood of the Columbia.

I omitted to state that I spent several days trying to gauge the Willamette between the head of Sauvie's Island and the foot of Post-Office Bar, but without success, the current being variable and sluggish.

On the section sheets annexed I have allowed for the difference of height of water at various points gauged, in order to make a fair comparison of the results.

Respectfully submitted.

ROBERT A. HABERSHAM,
Assistant Engineer.

Col. JOHN M. WILSON,
Major Corps of Engineers, U. S. A.

No. 1.—*Gauging the Willamette River, Oregon, one-quarter of a mile below Portland, September* 12 *and* 13, 1876.

Mean height of water, 3.6 feet above zero.

Section.	Area, square feet.	Mean velocity, feet, per minute.	Volume in cubic feet per minute.	Section.	Area, square feet.	Mean velocity, feet, per minute.	Volume in cubic feet per minute.
1	960	11.4	10,924	10	2,750	24.0	66,000
2	1,440	17.2	24,768	11	2,745	26.2	71,919
3	1,465	20.4	29,886	12	2,770	27.8	77,006
4	1,525	21.0	32,025	13	2,775	28.0	77,700
5	1,770	19.2	33,984	14	2,370	27.0	63,990
6	1,975	21.1	41,672	15	1,680	39.2	65,856
7	2,220	22.6	50,172	16	726	31.2	22,645
8	2,475	22.5	55,687				
9	2,660	23.4	62,244	Total			786,478

Average velocity, 23.9 feet per minute.

No. 2.—*Gauging Swan Island Channel, (south,) September* 15, 1876—*last half of ebb tide.*

Mean height of tide-gauge, 3'.9 above zero.

Section.	Area, square feet.	Mean velocity, feet, per minute.	Volume in cubic feet per minute.	Section.	Area, square feet.	Mean velocity, feet, per minute.	Volume in cubic feet per minute.
1	555	40.0	22,200	12	460	34.8	14,008
2	1,095	44.2	48,399	13	410	23.8	9,759
3	1,095	53.4	58,473	14	355	No current	
4	1,130	53.8	60,794	15	375	No current	
5	1,130	53.4	60,342	16	450	No current	
6	1,130	46.6	52,658	17	535	No current	
7	1,065	52.4	55,804	18	610	No current	
8	915	54.6	49,959	19	560	No current	
9	815	48.8	39,772				
10	760	43.6	33,136				
11	600	42.8	25,680		14,045	Av. 45.54	Tot'l 530,984

1300×.3=390×45.55=17,764 to be deducted. Correction for difference in height of water=513,220 cubic feet per minute.

No. 3.—*Gauging Swan Island Channel (north)—last half of ebb tide.*

Surface of water, September 18, 4.5 above zero.

Section.	Area, square feet.	Mean velocity, feet, per minute.	Volume in cubic feet per minute.	Section.	Area, square feet.	Mean velocity, feet, per minute.	Volume in cub'c feet per minute.
1	143	No current	....	7	2,507	30.0	75,210
2	420	No current	....	8	2,632	23.4	61,589
3	778	14.9	11,592	9	2,093	23.1	48,348
4	1,315	14.3	18,805	10	86	No current	....
5	1,813	15.0	27,195				
6	2,223	18.8	41,792		14,010	Av. 19.95	Tot'l 284,531

350×.9=315.0×19.95=6.278 cubic feet per mile to be deducted. Correction for difference in height of water= 278,253
Add south channel 513,220

791,473

A correction for increase of velocity will still further reduce the difference.

A.—*Current measurements in north channel, Swan Island, Lower Willamette River.*

Date.	Section.	Height of water above zero, in feet.	Area of sections, square feet.	Mean velocity in feet per minute.	Discharge in feet per minute.
April 4, 1877	......	10.5	21,142	63.75	1,347,802
April 5, 1877	1	9.6	5,775	67.27	388,484
	2	9.6	8,259	67.07	553,462
	3	9.6	6,503	56.55	360,745
Total	......	....	20,537	Av. 63.43	1,302,691
April 6, 1877	1	9.0	5,644	58.06	327,961
	2	9.0	8,115	64.74	525,365
	3	9.0	6,375	54.05	348,569
Total	......	....	20,134	Av. 59.64	1,201,895
April 7, 1877	1	8.5	5,535	65.22	361,993
	2	8.5	7,995	57.69	461,232
	3	8.5	6,269	50.85	318,779
Total	......	....	19,799	Av. 57.68	1,142,004

B.—*Current measurements in south channel, Swan Island, Lower Willamette River.*

Date.	Section.	Height of water above zero, in feet.	Area of sections, square feet.	Mean velocity in feet per minute.	Discharge in feet per minute.
April 4, 1877	1	10.5	3,895	41.09	160,046
	2	10.5	3,140	41.09	129,023
	3	10.5	3,927	41.09	161,360
	4	10.5	5,113	51.72	264,444
	5	10.5	5,544	54.54	302,370
	6	10.5	3,707	55.55	205,924
Total	......	......	25,326	Av. 48.29	1,223,167
April 5, 1877	1	9.6	3,517	39.41	138,605
	2	9.6	2,857	37.99	108,537
	3	9.6	3,644	43.47	158,405
	4	9.6	4,830	50.00	241,500
	5	9.6	5,261	46.15	242,795
	6	9.6	3,419	54.54	186,466
Total	......	......	23,528	Av. 45.75	1,076,308
April 6, 1877	1	0.0	3,265	41.67	136,053
	2	9.0	2,668	40.00	106,720
	3	9.0	3,455	44.12	152,435
	4	9.0	4,641	46.09	213,904
	5	9.0	4,915	53.57	262,297
	6	9.0	3,067	50.85	155,957
Total	......	......	22,011	Av. 46.67	1,027,366

No. 4.—*Gauging Willamette River, ½ mile above slough.*

Surface of water, September 29, 3.0 feet above zero.

Section.	Area.	Mean velocity.	Volume in cubic feet per minute.	Section.	Area.	Mean velocity.	Volume in cubic feet per minute.
		Ft. per min.				*Ft. per min.*	
1	4,255	20.4	86,802	4	5,671	24.0	136,104
2	9,624	25.3	243,487	5	7,279	21.6	157,226
3	6,250	27.7	115,895				
Total							739,514
Add volume due to difference in height of water 1500 × .0.6 × 23.8, (average velocity)							21,420
							760,934
Allowing 1 foot per minute = loss of velocity from loss of head							33,079
Total							794,013

No. 5.—*Gauging Willamette Slough, ½ mile below its head.*

Surface of water, September 22, 4.2 feet above zero.

Section.	Area.	Velocity.	Volume discharged.	Section.	Area.	Velocity.	Volume discharged.
		Ft. per min.	*Cu. ft. per min.*			*Ft. per. min.*	*Cu. ft. per min.*
1	680	75.0	51,000	5	1,740	78.7	136,938
2	1,750	71.4	124,950	6	1,695	85.5	144,922
3	2,080	75.0	156,000	7	1,715	78.7	134,970
4	1,800	74.1	133,380	8	865	78.7	68,075
Total							950,235
Average velocity in feet per minute							77.1

No. 6.—*Gauging Willamette Slough, 1½ miles below its head.*

Surface of water, September 22, 4.2 feet above zero.

Section.	Area.	Velocity.	Volume discharged.	Section.	Area.	Velocity.	Volume discharged.
		Ft. per min.	*Cu. ft. per min.*			*Ft. per min.*	*Cu. ft. per min.*
1	285	62.4	17,784	7	1,712	72.0	123,264
2	1,170	62.4	73,008	8	1,655	67.0	107,535
3	1,725	80.0	138,000	9	1,535	50.0	76,750
4	1,800	82.0	147,600	10	1,205	50.0	60,250
5	1,775	80.0	142,000	11	400	50.0	20,000
6	1,737	72.0	125,064	12	195	50.0	9,000
Total							1,040,255
Average velocity in feet per minute							64.8

No. 7.—*Gauging Columbia River above Saint Helen's Bar.*

Surface of water, October 5, 4.0 feet above zero.

Section.	Area.	Velocity.	Volume discharged.	Section.	Area.	Velocity.	Volume discharged.
		Ft. per min.	*Cu. ft. per min.*			*Ft. per min.*	*Cu. ft. per min.*
1	721	66.7	48,091	11	6,897	103.4	713,150
2	1,626	76.2	123,901	12	6,362	117.6	748,171
3	2,257	96.8	218,478	13	6,138	109.2	670,270
4	2,976	115.3	343,133	14	5,761	95.2	548,447
5	3,421	122.5	419,072	15	5,104	99.0	505,296
6	4,368	133.3	582,254	16	4,428	103.1	456,527
7	5,582	136.4	761,385	17	3,866	88.5	342,351
8	6,521	103.4	674,271	18	3,082	75.2	231,766
9	7,215	115.3	831,889	19	2,121	66.7	141,470
10	7,366	101.7	749.122	20	821	66.7	54,761
Total							9,163,805
Average velocity of current in feet per minute							99.6

No. 8.—*Gauging Columbia River below Saint Helen's Bar, October* 6 *and* 9.

Surface of water 4.0 above zero.

Section.	Area.	Velocity.	Volume discharged.	Section.	Area.	Velocity.	Volume discharged.
		Ft. per min.	*Cu. ft. per min.*			*Ft. per min.*	*Cu. ft. per min*
1	1,755	100.0	175,500	23	3,333	142.9	276,286
2	4,212	130.4	549,245	24	3,487	136.3	475,278
3	5,440	136.3	741,472	25	3,261	125.0	407,625
4	4,446	125.0	555,750	26	2,761	121.1	334,357
5	3,744	130.4	488,218	27	2,266	125.0	283,250
6	3,275	133.3	436,557	28	1,853	130.4	241,631
7	3,100	127.6	395,560	29	1,406	115.4	162,252
8	2,749	130.4	348,470	30	1,579	127.6	201,480
9	2,164	100.0	216,400	31	1,606	92.3	148,234
10	1,521	93.7	142,518	32	1,683	103.4	174,022
11	1,111	96.8	107,545	33	1,864	103.4	192,738
12	959	78.9	75,665	34	1,805	101.7	183,568
13	907	77.9	70,655	35	1,875	95.2	178,500
14	935	98.3	91,910	36	1,905	101.7	193,738
15	1,128	122.4	138,067	37	1,980	95.2	188,496
16	1,452	107.2	155,654	38	1,890	85.7	161,973
17	1,584	111.1	175,982	39	1,810	84.7	153,307
18	1,584	117.9	186,754	40	1,990	80.0	159,200
19	1,639	127.7	209,300	41	1,885	86.9	163,806
20	2,239	136.4	305,400	42	1,565	78.8	123,322
21	2,673	130.4	348,559	43	1,210	54.5	65,945
22	2,899	157.9	457,752	44	450	38.9	17,505
Total							10,859,446
Average velocity in feet per minute							108.9

No. 9.—*Gauging Willamette River,* 1,000 *feet above Three-Tree Island.*

Surface of water October 18, 4.2 feet above zero.

Section.	Area.	Velocity.	Volume discharged.	Section.	Area.	Velocity.	Volume discharged.
		Ft. per min.	*Cu. ft. per min.*			*Ft. per min.*	*Cu. ft. per min.*
1	590	0.0	....	9	1,504	13.8	20,755
2	4,704	21.8	102,547	10	1,851	10.7	19,806
3	4,902	18.4	90,197	11	1,955	0.0	....
4	3,349	19.0	63,631	12	1,352	0.0	....
5	1,940	18.1	35,114	13	894	0.0	....
6	1,134	22.2	25,175				
7	694	23.7	16,448	Total			392,033
8	918	20.0	18,360				
Average velocity, in feet, per minute							18.6
Average velocity, during flood-tide, in feet, per minute							2.60

Measured during spring-tides only. The outward current during neap-tides is so variable that it cannot be accurately measured.

No. 10.—*Gauging Coon Island Slough.*

Surface of water October 13, 3.2 feet above zero.

Section.	Area.	Velocity.	Volume discharged.	Section.	Area.	Velocity.	Volume discharged.
		Ft. per min.	*Cu. ft. per min.*			*Ft. per min.*	*Cu. ft. per min.*
1	104	37.5	3,900	4	940	36.4	34,216
2	950	66.7	63,365	5	925	55.5	51,337
3	990	55.5	54,945	6	475	55.5	26,361
Total							234,124
Average velocity during neap-tides, in feet, per minute							51.2

During the spring-tides there is very little current through this channel.

No. 11.—*Gauging mouth of Willamette.—Middle channel.*

Surface of water October 16, 4.0 feet above zero.

Section.	Area.	Velocity.	Volume discharged.	Section.	Area.	Velocity.	Volume discharged.
		Ft. per min.	*Cu. ft. per min.*			*Ft. per min.*	*Cu. ft. per min.*
1	654	15.1	38,867	8	1,650	20.0	91,300
2	1,920			9	1,285		
3	2,285	21.9	94,498	10	870		
4	2,030			11	560		
5	1,700	16.4	84,788	12	200		
6	1,695						
7	1,775						
Total during spring-tides only							309,453
Average velocity, in feet, per minute							18.4

Abstract of proposals for furnishing the United States with a tug-boat, when required, during the year 1877, opened by Maj. John M. Wilson, Corps of Engineers, February 8, 1877.

No.	Names and residence of bidders.	Furnishing boat when required during the year 1877, per month.	Remarks.
1	Bailey & Taylor, Portland, Oreg	$585 00	Contract awarded.
2	S. S. Douglass, Portland, Oreg	600 00	
3	C. R. Wilson & Henry Wilson, Portland, Oreg	700 00	

Abstract of contract for the improvement of the Lower Williamette and Columbia Rivers, in force during the fiscal year ending June 30, 1877.

No.	Names and residence of contractors.	Date of contract.	Subject of contract.	Price per month.
1	Bailey & Taylor, Portland, Oreg	Feb. 12, 1877	Hire of steam-tug as tender to United States dredge, when required, during the year ending June 30, 1877.	$585 00

REPORT OF THE BOARD OF ENGINEERS FOR THE PACIFIC COAST.

OFFICE BOARD OF ENGINEERS PACIFIC COAST,
San Francisco, Cal., April 9, 1877.

GENERAL: In accordance with instructions from the Chief of Engineers, dated July 26, 1876, the Board of Engineers for the Pacific coast met in Portland, Oreg., in August last to consider the project of Maj. John M. Wilson, of the Corps of Engineers, for the improvement of the Lower Willamette and Columbia Rivers, from Portland to the sea.

After personally examining these rivers and Major Wilson's charts and project, the Board presented a preliminary report under date of August 24, 1876, wherein it was recommended that, before final action was taken, certain further surveys and examinations should be made, in order that the Board might be fully informed upon the subject under consideration.

These examinations and surveys were made and charts prepared during the fall of 1876, and on January 17, 1877, the Board reconvened at San Francisco, Cal., all the members being present, including Maj. John M. Wilson, Corps of Engineers, who, in accordance with Department letter of July 26, 1876, became a member of the Board while this subject was under consideration.

The Board has examined the plans of Major Wilson, and, after careful consideration of all the data laid before it, respectfully submit the following

REPORT.

The project of Major Wilson embraces plans for the improvement of Swan Island Bar, Post-Office Bar, and the bar at the mouth of the Willamette, (these three being in the Willamette River,) and also for the improvement of Saint Helen's Bar in the Columbia River.

In presenting its report the Board deems it best to discuss each bar separately, beginning at Portland and proceeding toward the mouth of the Columbia.

Opposite Portland the channel of the Willamette River presents a depth of from 20 to 40 feet at low-water. Lower down the river widens, giving a consequent decreased velocity. It begins to shoal a short distance above Swan Island, 3 miles below Portland.

At this place there are two channels: one, north of the island, the present ship-channel, being about 600 feet wide, and from 20 to 50 feet deep; the other, south of this island, is about 1,900 feet wide, with a depth of from 4 to 7 feet at low-water.

About three-quarters of a mile above the island the bar commences to appear, and through this a channel, about 100 feet wide and 17 feet deep, at low-water, has been cut, connecting deep water in the river above with the deep channel north of Swan Island; and dredging has continued annually for the past nine years, each year's freshet partially filling the cut.

Major Wilson's plan proposed to close one of these channels, and he presented projects for both, favoring, however, the closing of the north, or present, ship-channel.

The gauging of the Willamette River, a quarter of a mile below Portland, September 12 and 13, with the water $3\frac{1}{4}$ feet above zero, showed an average velocity of 23.9 feet per minute, and a volume of 786,478 cubic feet per minute.

September 15, the river being 3.9 feet above zero, the volume passing through the South Swan Island Channel was found to be 530,984 cubic feet per minute, with an average velocity of 45.54 feet per minute.

And September 18, the river being $4\frac{1}{4}$ feet above zero, the volume in the North Swan Island Channel was 267,261 cubic feet per minute, having an average velocity of 19.93 feet per minute.

Thus showing the quantity in the south channel to be nearly twice as large as that in the north channel at this stage of the river.

These determinations are somewhat anomalous, but, being the results of actual measurements, we suppose they must be accepted as correct.

We say anomalous, because while the areas of the sections of the two channels south and north of Swan Island do not greatly vary, (that of the north channel being the larger, however, and having a greater depth,) yet the mean measured velocity of the water in the south channel was more than twice as great as that in the north channel, giving as a result twice as much water through the south as through the north channel, at the stages above mentioned. The usually accepted hydraulic formulæ for the flow of rivers would give directly contrary results.

Again, it seems strange that, if the water in the south channel has twice the velocity of that in the north channel, the south is not the deeper channel of the two.

Accepting the determinations as correct, however, we must conclude that there are certain conditions governing the flow of water through these channels which remain, as yet, undiscovered.

Some six week later, the level of the river being 6.2 feet above zero, it was again gauged, and the discharge found to be as follows:

	Cubic feet per minute.
Just below Portland	3,095,400
South Swan Island Channel	1,802,470
North Swan Island Channel	1,369,138

the increased volumes being attended with accelerated velocities.

This result is again anomalous, for, while we have added much more area of cross-section of water-way to the south channel, on account of

its greater width, than to the north channel, yet, although the flow of water through both channels has been greatly increased by the additional height of the river, the relative increase of flow has been in favor of the north channel. This is contrary to all preconceived ideas on the subject, and contrary to the result given by all formulæ applicable to its determination.

This leads us again to conclude that there must be some unknown factor bearing on the solution of the relative flow through these two channels. Perhaps future researches may discover it, and we recommend further investigations.

Borings were made in each channel to the depth of 21 feet below the plane of low-water.

The material in the south channel was found to be sand, with occasional layers of gravel from one to two inches in thickness.

In the north channel the bottom was blue clay, sand, and gravel at various localities; the filling in the channel already cut through the bar being a coarse sand and gravel, the latter sometimes as large as a pigeon's egg.

After careful consideration, the Board deems it best to close the south channel by a dike of brush and stone 7,000 feet long, running from the upper end of Swan Island to the south shore, the top of the dike to be at ordinary low-water, or about two feet above the level of the river at dead low-water.

In the opinion of the Board such a construction would cause the north channel, through Swan Island Bar, to be scoured out, and would render further dredging unnecessary.

The reasons of the Board for selecting the north channel for navigation and closing or partially closing the south channel are:

1st. The north is the present navigable channel, and it can be more easily and cheaply improved than the south channel.

2d. A dike across the south channel will not interfere with the commerce of the river, whereas one across the north channel would interrupt that commerce, for, if it be decided to close the north channel, it is evident that this closure cannot be completed until a navigable passage is opened through the south channel. This would necessitate a very large quantity of dredging, and consequent expense, in opening and keeping open the south channel for commercial purposes, before closing the north channel.

If the difference of the cost of the two projects be left out of consideration, (and if we could be sure that the sand and gravel to be washed out of the south channel if the north channel be closed would not eventually give trouble in the river below Swan Island,) the Board would prefer to make the south channel the navigable one, being led to this choice by the fact that it is the shorter of the two channels, and the river-bottom here (being mostly sand) would be more easily eroded than in the north channel, where it is of blue clay in certain portions.

The estimated cost of the dike across the south channel, 7,000 feet long, is 34,000 cubic yards, at $1.50 per yard, amounting to $51,000.

From Swan Island to the head of Willamette Slough the river presents an excellent channel, with a depth of from 20 to 47 feet at low-water, except at one locality, about a mile below the island, where, for a distance of about 500 feet, there is a depth of only 18 feet at low-water.

Just below the head of the Willamette Slough Post-Office Bar occurs, and in order to remove this it was proposed to partially close this slough.

A careful examination showed the following to be the case here:

The fall in the Willamette River during low-water is as follows:

Calling the zero of the gauge at the foot of Yamhill street, Portland, 100,000 during low-water, the gauge at Portland reading 3 feet, the elevations at different points are as follow:

At Portland	103,000
At head of Willamette Slough, $9\frac{1}{4}$ miles below Portland	102,200
At mouth of Willamette River, $12\frac{5}{8}$ miles below Portland	102,200
At Saint Helen's, $27\frac{5}{8}$ miles below Portland, by the rivers	101,500
At Saint Helen's, $32\frac{1}{4}$ miles below Portland, by Willamette Slough	101,500

Showing the fall, at this stage of the rivers, to be:

From Portland to the head of the slough	$\frac{8}{10}$ foot.
From head of slough to mouth of Willamette	None.
From head of slough to Saint Helen's	$\frac{7}{10}$ foot.

The borings showed the material forming Post-Office Bar to be sand, similar to that in the Willamette River near Swan Island.

The gauging of the Willamette River a half mile above the head of the slough, on September 29, the level of the river being $3\frac{1}{2}$ feet above zero, showed a volume of 739,514 cubic feet per minute, while that of the slough, the gauge reading 4.2 above zero, shows a volume of 1,040,255 cubic feet per minute.

Further observations in gauging the Willamette River below the head of the slough showed the volume of the flood to exceed that of the ebb tide about 150,000 cubic feet per minute, and that a large amount of water at this stage of the river, from the Columbia, runs up the Willamette River and then escapes down the slough.

As the distance from Saint Helen's, by way of the rivers, which are wide, to the head of the slough is about 18 miles, and by way of the slough, which is narrow, is about 23 miles, the flood tide by way of the rivers reaches the head of the slough and begins to run down it before the flood reaches that point by way of the slough.

The facts thus presented show that during ordinary low-water the entire volume of the Willamette, in addition to a large quantity from the Columbia, passes down the Willamette Slough.

In the opinion of the Board, the best plan for removing Post-Office Bar would be to entirely close the Willamette Slough by a dam near its head; but as this is a navigable channel, and has many settlers on its banks, and as it is used by steamers running to Astoria when the Columbia River is closed by ice above Saint Helen's, the Board recommends that a dike of brush and stone be built to the height of ordinary low-water, or 2 feet above the zero of the gauge, on the shoal in the slough about 2,300 feet below its head, leaving a channel 100 feet wide in the middle with a depth of 6 feet at low-water, the sides of this channel to be cribs 50 feet long by 25 feet wide, the bottom well paved to prevent erosion.

It is estimated that by this plan at least seven-eighths of the water now passing down the slough will be kept in the Willamette River and will be sufficient not only to cut and keep open a channel through Post-Office Bar, but also to materially aid in removing the bar at the mouth of the river.

Such a dam or dike, 800 feet long, with an average height of 15 feet, except where the opening is left, would contain 17,000 cubic yards, and would cost as follows:

17,000 cubic yards, at $1.50 per yard	$25,500 00
100 feet of crib-work, at $25 per foot	2,500 00
Total	28,000 00

It is believed that after the completion of such a dike further dredging will be unnecessary at Post-Office Bar.

From the lower end of this bar there is a channel with a depth of from 20 to 45 feet, until we reach the mouth of the Willamette River, about 2½ miles distant, where another bar is found.

The river again widens here, and during low-water on the ebb-tide a large volume of water passes through Coon Island Slough, just above the bar.

A careful examination shows this bar to consist of a fine sand almost identical with that of Saint Helen's Bar in the Columbia, showing plainly that it comes from that river.

During the freshets in the Columbia River a large volume of water pours through Percy's and Columbia Sloughs, opposite the bar, meeting another volume passing up the Willamette River, part of which escapes down Coon Island Slough, still more down the Willamette Slough, and the remaining portion of this upward flood assists in raising the Willamette River to a considerable height as far up as the falls at Oregon City, a distance of about 25 miles from its mouth.

During neap-tides it was found that 234,125 cubic feet per minute passed out through Coon Island Slough, while there was no perceptible current through the main channel of the Willamette River. This occurred when the water was 3.2 feet above zero. At a later date when the water was 10 feet above low-water mark the discharge through the main channel was 3,304,608 cubic feet per minute; that through Coon Island Slough, 721,728 cubic feet per minute.

It is the opinion of the Board that the partial closing of Willamette Slough, as above recommended, will deepen the water over the bar at the mouth of the Willamette River, but if sufficient depth is not thereby obtained, then it will become necessary to contract the river here so as to hold the water at the low stage within such limits as will secure the necessary scour.

To do this it is recommended—

1st. That Coon Island Slough be closed at its head by a dike running from Sauvie's Island to Coon Island, the face of the latter island being revetted.

2d. If this construction does not obtain the required depth of water over the bar at the mouth of the river, then a dike should be constructed on the opposite side, as shown on the drawing, from Nigger Tom Island to the main shore just above the mouth of Columbia Slough, the face of Nigger Tom Island being revetted, and, if necessary, a dike run from its lower end into the Columbia River for a distance of about 600 feet.

These dikes should be carried up to the height of ordinary low-water, or say 2 to 3 feet above zero. They will at that stage hold the water of the Willamette River within them, and will, during the season of freshets in the Columbia River, keep behind them and turn into the Columbia the sediment in the water from Percy's and Columbia Sloughs below the plane of the top of the dike.

In the opinion of the Board such constructions would, beyond doubt, keep open the channel at the mouth of the Willamette, and would go far to, if not entirely, prevent the deposits now annually occurring on this bar during the freshets in the Columbia River.

Such constructions would cost as follows:

Coon Island dike, 1,400 feet long, 38,000 cubic yards, at $1.50	$57,000 00
Coon Island revetment, 1,100 feet long, at $4.50 per foot	4,950 00

Nigger Tom upper dike, 2,300 feet long, 12,000 cubic yards, at $1.50	$18,000 00
Nigger Tom lower dike, 600 feet long, 8,000 cubic yards, at $1.50	12,000 00
Nigger Tom revetment, 2,000 feet, at $4.50 per foot	9,000 00
Total	100,950 00

Leaving the Willamette River we pass down the Columbia with a good channel until we reach Saint Helen's Bar, about 27 miles, by the rivers from Portland.

This bar is 2 miles long, crossing the river diagonally from the foot of Sauvie's Island to a point nearly opposite Columbia City, with deep water on each side.

The east bank of the river from opposite Warrior Rock to the lower end of the bar is low, from 5 to 10 feet above low-water, and is composed principally of sand, with occasional veins of clay; it has no stability, and, yielding each year to the floods, widens the channel and lessens the depth of water on the bar.

As we approach the foot of Sauvie's Island, coming down stream, Lewis River and Vancouver Slough empty into the Columbia from the east side, while Warrior Rock, a bold point, juts out from the west shore like a wing-dam, just before the bar is reached. Here the river is only 2,000 feet wide, but has a depth of from 50 to 105 feet, and the volume of discharge, when the river was 4 feet above low-water, on October 5, was found to be 9,163,805 cubic feet per minute. Below Sauvie's Island the Willamette Slough pours out, giving a wide and deep channel on the Oregon side of the bar. The river below Saint Helen's, October 6, the water still being 4 feet above zero, showed a volume of 10,859,446 cubic feet.

Allowing in round numbers 1,000,000 cubic feet for the discharge of the slough, there is a difference of about 7 per cent. in the measurements. The latter is considered the more accurate, the weather having been perfectly calm when it was taken, which was not the case in the former.

On the Washington Territory side, near the lower end, is a plateau covering an area of about 300 acres, having upon it a depth of from 1 to 15 feet of water. The bottom, for a depth of from 2 to 6 feet, consists of gravel containing granite, gneiss, quartz, &c., similar to the bars in the Upper Columbia, resting upon a bed of hard material supposed to be rock.

The ship-channel, until within the past year, has been at the lower end of this bar near the plateau just mentioned, with a depth of about 17 feet at low-water. This has been the best channel over this bar until the fall of 1876. Under ordinary circumstances the Board would have preferred to maintain this channel, but the freshet of 1876 filled it in places about 4 feet and opened another at the upper end of the bar, bringing at the latter place the 18-feet curves within 400 feet of each other, where in 1875 they were 900 feet apart, and gaining a depth of from 15½ to 18 feet at low-water, where in 1875 it was from 12 to 16 feet deep.

Doubtless a good ship-channel may be created by suitable constructions either at the upper or lower end of Saint Helen's Bar, but in view of the recent change the Board considers it best to locate two dikes across the bar on each side of the present ship-channel, about a half mile below the lower end of Sauvie's Island; the dikes to be each about 950 feet long, flaring at the upper end to a width of 800 feet, and narrowing to 300 feet at the lower end. It is possible that eventually it may be necessary to connect the one on the Oregon side with Sauvie's Island.

The Board, Lieutenant-Colonel Stewart dissenting, presents this plan as the best under present circumstances, believing that it will cut out and keep open a channel through the bar at this its narrowest and deepest part. At the same time it deems it possible that future freshets may make such changes before work can be commenced as to prove the lower end of the bar to be the better place for the dikes, the cost and extent of which would be about the same in either case.

The cost of this improvement would be as follows:

1,900 feet dike=58,000 cubic yards, at $1.50 per yard = $87,000.

From Saint Helen's Bar to the sea the only bar now existing that gives trouble is that below Snag Island at the junction of Woody Island and Cordell Channels. As there is a depth of not less than 15 feet on this bar at low-water, and two flood-tides daily, with a rise of from 6 to 8 feet, the Board deems it unnecessary at present to recommend further action here than to scrape the bar occasionally and to have it thoroughly buoyed.

It is thought that if funds were available, the whole of the work above mentioned could be executed in two seasons.

The estimated cost of the foregoing project is as follows:

Swan Island dike	$51,000 00
Willamette Slough dike	28,000 00
Mouth of Willamette—dams and revetments	100,950 00
Saint Helen's dikes	87,000 00
Contingencies and engineering, 12 per cent	32,024 00
Total	298,974 00

Four charts, showing the extent and location of the proposed dikes, are transmitted herewith.

Respectfully submitted.

G. H. MENDELL,
Major of Engineers.
R. S. WILLIAMSON,
Lieutenant-Colonel, Corps of Engineers.
C. SEAFORTH STEWART,
Lieutenant-Colonel of Engineers.
B. S. ALEXANDER,
Lieutenant-Colonel of Engineers, President of the Board.

I coincide in the views of the Board, except in reference to closing the south Swan Island Channel, believing, from all the information before me, that the north should be closed and the south left open.

Further investigations will be made at this place in reference to volume and velocity, and, should similar results be obtained as in September, 1876, I will present my views in full upon the subject.

Respectfully submitted.

JOHN M. WILSON,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

LETTER OF THE CHIEF OF ENGINEERS.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., May 21, 1877.

SIR: The report of April 9 from the Board of Engineers for the Pacific coast, which had under consideration your project for the improvement

of the Lower Willamette and Columbia Rivers, is approved, and the conclusions of the Board concurred in. Future appropriations for these works will, therefore, be expended in accordance with the plans and recommendations therein set forth.

In adopting the recommendations of the Board, as to the propriety of closing the south channel of the Willamette at Swan Island, it is not intended that you should discontinue the observations you have in view for the further investigation of the regimen of the river in that vicinity, nor to deprive you of the opportunity of further presenting your views in favor of the closure of the north channel.

By command of Brigadier-General Humphreys.

Very respectfully, your obedient servant,

JOHN G. PARKE,
Major of Engineers.

Maj. JOHN M. WILSON,
Corps of Engineers.

JJ 2.

IMPROVEMENT OF THE UPPER WILLAMETTE RIVER, OREGON.

In my last annual report I described fully this river, its floods, and the causes of the various bars that are impediments to navigation, and will now take up the subject by sections, as then discussed.

1. THE UPPER SECTION FROM EUGENE TO CORVALLIS.

This section of the river, comprising a length of about 56 miles, is subject to constant changes, so much so that even within the last 20 years pilots say that they have never run the same continuous channel in reaches from 5 to 10 miles above Harrisburg for two consecutive seasons. Between Eugene and Harrisburg, a distance of 23½ miles, the fall is 105.9 feet, or at the rate of 4½ feet to the mile; between Harrisburg and Corvallis, a distance of 35 miles, no line of levels has ever been run, to my knowledge, but I believe the fall to be over 3 feet to the mile. No steamboat has ascended to Eugene since the spring of 1876, not on account of lack of water, because the freshets in the winter and spring of 1876 and 1877 filled the stream, rising to a height of over 30 feet above low-water at Salem, but because nearly all the freight from Harrisburg and Eugene had already been sent by railroad. I therefore determined to descend during low-water from Eugene to Albany, a distance of about 68 miles, in a skiff, and made the trip on June 11 and 12 of the present year.

A careful examination showed that many changes had occurred above Harrisburg since the survey of 1875, and that others had taken place since last season. At several points above Corvallis the river separates into two or more channels, its capacity being correspondingly reduced and bars and shoals being formed. These bars are composed of loose gravel washed from the drift formation of the banks, and are constantly changing their shape. In approaching one of the rapids, my skiff, drawing only a few inches, grounded, and the gravel rolling down stream rattled against its sides like hail. The slope of this section of the river is entirely too great to render it permanently navigable at all seasons by contracting the channel, and I believe that the only plan of permanent improvement for it would be by a system of locks and dams, and until the

regimen of the river becomes nearer fixed, I would not recommend that this plan be adopted. I think, however, that if the water should be partially controlled by cutting off certain sloughs and by building a few wing-dams in the vicinity of the worst bars, so as to confine the river as much as possible during low-water in one channel, then, with a self-propelling snag-boat, with a scraper and pile-driver attached, I could keep the river open for light-draught steamers for at least three-fourths, and perhaps the whole year.

I would start this boat from Eugene as the freshet commences to subside, and by the time of low-water the bars would be scraped and the worst snags removed. With the pile-driver the crew could easily and quickly build temporary dams to sluice out a channel where scraping would not be sufficient. The localities in this section where the greatest waste of water occurs, and which first require attention, are at White's Rapid, Saw-mill Bend, Trout Bar, Ohio Chute, Bromley's Bend, Alford's Chute, Wilson's Chute, Peoria, and Centennial Slough; at Ohio Chute and Centennial Slough the channel has vastly improved since last year.

In addition to these troubles snags and drift-logs are numerous, and each freshet adds to their number; annual appropriations will be required to remove these, and will continue to be necessary until the timber shall have been removed from the immediate banks of the river.

For this section I would therefore recommend the construction and maintenance of a steam snag-boat with scraper and pile-driver attached, and that about 6,000 feet of cut-off dams and 8,000 feet of wing dams be built at the localities already mentioned, where the greatest waste of water and the most trouble occurs.

After the construction of these dams, and of the new snag-boat, I think that an annual appropriation of $6,000 will be sufficient to keep this section of the river open for light-draught boats for at least three-fourths, and perhaps the entire year.

Up to this time the only work done above Corvallis consists of the removal of drift and snags at different points, the greater portion having been taken from Booneville Slough, Centennial Slough, mouth of Long Tom, Wilson's and Ohio Chutes, and Harrisburg Bend.

2. THE LOWER SECTION—CORVALLIS TO PORTLAND.

As stated in my last report, but little change has occurred in the general direction of the channel in this section for a number of years; light-draught boats can generally run to Salem at all seasons of the year, and to Corvallis at all times except during lowest water.

The difficulties in the way of navigation consist of numerous gravel-bars, some rocky ledges, and various accumulations of drift and snags. Many of these bars have been greatly improved by constructing wing-dams, but there are several still very troublesome; these will be enumerated in another portion of this report.

I believe that the channel in this section of the river may be maintained so as to be navigable the entire year for boats drawing 2½ feet. To do this, I think, after removing some rocks, the present snag-boat, if supplied with propelling-power, a scraper, and a pile-driver, will be sufficient for the present; the boat can be laid up at Corvallis during high water, and, as the freshet recedes, can drop down, scraping bars, removing snags, and building short dams where necessary to sluice out a channel that cannot be improved by scraping. I do not consider it necessary to continue the construction of extensive dams after this season, but prefer to wait until I can have a complete and accurate sur-

vey made of the whole river between Corvallis and Portland before offering any detailed and elaborate plan for the permanent contraction of the channel. After the completion of work this season, and removing certain rocks above Oregon City hereafter, I think a good snag-boat can keep the river open throughout low-water season by promptly proceeding to any point where trouble may occur. The cost of supplying the present snag-boat with propelling-power, scraper, pile-driver, &c., would be $6,500. A complete survey of the river between Corvallis and Portland, a distance of 114 miles, would cost about $12,000.

BARS, ETC., BETWEEN CORVALLIS AND OREGON CITY.

As previously stated, obstructions to navigation exist at various points in this section of the river. Proceeding from Corvallis down stream we find the first at

HALF MOON BEND, UPPER BAR,

four miles below. The river at this point is 440 feet wide. The left bank is about 15 feet above low-water, nearly vertical, formed of sand and clay, and yields readily to erosion; the right shore is a shelving bank of gravel, of which the obstructing bar is a continuation. During the summer of 1876 two wing-dams of nearly equal length were built just above the bar, one on each side. The good effected by these dams is shown by the fact that the depth over the bar has been increased from 22 to 51 inches. During the high-water last winter the bank on the left side and the gravel on the right, upon which the shore-ends of the dams rested, were cut away, leaving gaps which were closed this season.

The lower bar is situated one-third of a mile farther down. The river here is 450 feet wide, very crooked for some distance above and below the bar, and for several years has been shoaling, until at length a bar has been formed. A survey of this locality was made in June, 1877, and a dam constructed which it is hoped and expected will sluice out a channel very soon.

BOWER'S BAR.

This obstruction, next in order, is situated about 7 miles below Corvallis. A crib-dam was built here in 1872, and a channel obtained 100 feet wide and 42 inches deep, too narrow to afford sufficient water-way at the low stage of the river. The water being unable to erode the hard bottom on which the dam was built, cut a passage through the loose gravel-spit 500 feet above and thus diverted about one-third of the volume of the river from the steamboat-channel.

As this cut was enlarging rapidly, it was decided to close it in the summer of 1876 by means of a dam, to prevent the whole river turning into a circuitous channel. Soon after the completion of the dam and before its acceptance, it was ruptured by the water and a length of 20 feet carried away, causing such a sluice through the opening that in a short time the depth in the gap was increased from 6 to 11 feet; this was speedily repaired, but was again badly injured by the freshet in the fall of 1876. The volume passing through the gap was, however, found to be much less this spring than last year, the greater portion of the river being retained in the straight channel. In June, 1877, the dam was strengthened and repaired and the shore above revetted.

PINE TREE BAR.

The next difficulty heretofore has been encountered at this rapid about 14 miles below Corvallis. The river is 480 feet wide; on the right side

(concave) the bank is 15 feet high, and of sandy soil, overlying gravel which is from 3 to 5 feet thick; under this is a hard-pan, a ledge of which extends out into the river. On the opposite side the bank is low and shelving, composed of loose gravel thinly covered down to the low-water line with willows of recent growth. Dams were built on each side last year, by which the depth was increased from 24 inches to 48 inches. One of the dams was somewhat injured by heavy drift-logs last winter, but has been repaired this season.

UPPER FICKEL'S BAR.

This obstruction is 19 miles below Corvallis. Previous to the construction of the dams at this locality last season, the steamboat-channel was close under the left bank, and so narrow as to make the passage difficult. By building a dam across this channel, and closing a narrow slough which made off from the river half a mile above, the entire volume was made to flow over the middle of the bar, and the consequent erosion produced a channel 4 feet deep, which it is hoped will be permanent.

LOWER FICKEL'S BAR

is one mile lower down, and almost identical in shape and general character with the upper bar of the same name. A subordinate channel, called Black Dog Slough, formerly left the river half a mile above, diverting considerable water. This was closed by a dam last summer, and another dam was built on the left side of the bar, which has greatly improved the channel, increasing the depth from about 2 to over 4 feet.

BUENA VISTA BAR.

The next impediment is 24 miles below Corvallis.

This has always been one of the worst places on the river, if not the very worst. A gravel-bar, 5,000 feet long, extends diagonally from the right toward the left shore. It is from 200 to 800 feet wide, and from 1 to 3 feet above low water. It divides the river into two channels, the left of which is the principal and only one navigable, carrying the whole volume of the water, except a small portion flowing through two streams which come over the head of the bar into the right channel, which is nearly slack-water. The river is from 600 to 900 feet wide, the left shore steep, the bank formed of stiff clay, which resists erosion; the other shore is low, of sand and loam, and subject to overflow. At the lower end of the long bar the obstruction occurs. The surface of the water at the low stage is nearly 2 feet lower in the right channel than in the left, and the tendency of the current is to flow across the whole bar toward the right side.

Last season it was determined to build a dam along the crest of this bar near its lower end, beginning at the point where the water commences to flow over, and running it parallel to the general direction of the stream as far as might be necessary to scour a channel through the lower end of the bar.

The work was staked out and the contractor instructed to commence at the upper end and rapidly build down stream, completing the dam as he progressed. Instead of this, he undertook, against the advice of the inspector of the work, to build from both ends toward the center, leaving the deepest part for the last, and, as a consequence, the current commenced cutting through the gravel, running at the rate of about 5

miles an hour, and before the gap could be closed made a cut 11 feet deep, and damaged his work very much. Assistant Engineer Habersham was at once sent to the locality, and with his energetic assistance, after changing somewhat the general direction of the lower portion of the dam, the work was completed. It was an exceedingly difficult job, and had Mr. Habersham not been on the ground I doubt whether the contractor would have succeeded.

The plan adopted was as follows: A line of piles 5 feet apart was driven to hard bottom throughout the length of the proposed dam. Just above the piles a course of gunny sacks, about three-quarters filled with gravel, was laid close together with their ends up and down stream. Next came a course of fascines of fir boughs, 20 feet long, their butt-ends down stream, resting on the sacks, and each weighted down with 2 or 3 sacks of gravel. Then a second course of sacks doubled the intervals filled with loose gravel. This process was repeated until the dam was built up to within a foot of the surface of the water. Then a line of stringers, logs about a foot in diameter, held by ropes to piles driven about 30 feet up stream, was laid on the crest of the dam and weighted down with fascines and gravel, the latter about 2 feet thick and raked smooth. The ropes holding the stringers were then cut. By building the dam in layers, the water was gradually diverted, but incessant watchfulness was necessary to prevent cutting the gravel around the piles. A scow-load of sacks of gravel was kept ready for immediate use, and this saved the work, as the gravel commenced washing out three times during the construction. This method of building *cheap* dams in swift water appears to be quite satisfactory. The effect of this dam was to wash away the lower end of the long bar, removing two smaller islands covered with young willows which projected above the water, deepening the channel and lessening the inclination over the bar. The winter flood did not injure the work, but in May, 1877, a raft of logs carried away about 60 feet, causing a sensible waste of water through the gap. This will be repaired, and additional work added this season. Two short dams were also built above the bar, cutting off minor channels running behind islands.

The next obstruction has hitherto been found at

LONG-CROSSING BAR,

twenty-seven miles below Corvallis. This is simply a wide portion of the river where the loss of velocity causes a bar. The steamboat-channel, where there was only about 24 inches depth at extreme low water, was formerly under the west shore. In the middle of the river there was only 12 inches. Last summer two wing-dams were built, concentrating the water in the middle of the stream, and sluicing out a channel $4\frac{1}{2}$ feet deep at low water.

HUMPHREY'S ROCKS,

thirty-one miles below Corvallis, is the next obstruction. There are two channels here. The eastern is obstructed by a bar, showing gravel on its surface, and is only navigable during the high stages of the river. Several years ago an attempt was made to divert sufficient water from the west channel to remove this bar, by constructing a wing-dam. The object in view was not accomplished. The west channel is, and will probably continue to be, the best for navigation, and it is possible that it may be necessary to entirely close the other. It is obstructed by a ledge of rocks, which, from all appearances, is the same on which

the gravel-bar at the head of the east channel rests, while the island between the two channels is a deposit of gravel and alluvium dropped below the ledge by the current, and afterward overgrown by vegetation. The gradual growth of this island has contracted the water-way, causing considerable erosion of the banks on both sides of the river. Forty-seven cubic yards of rock were removed from this ledge during the past summer, greatly improving the west channel.

ROCKY RAPID,

about 39 miles below Corvallis, was the next obstruction. A ledge of basaltic rock crops out from the east shore at low-water mark with a dip of about 4 degrees, running under water. On top of the ledge were a number of loose fragments of rocks of various sizes, which had from time to time injured steamers. These pieces were broken up by blasting, and a rough wall built with them on the ledge near the shore. An isolated rock was also removed from the channel. The bar is now in good condition, and has a depth of over 4 feet at low water upon it.

EOLA BAR,

forty-two miles below Corvallis, is the only obstruction between Rocky Rapid and Salem. The channel is shallow and very crooked, and generally gives trouble toward the end of the low-water season. No work has heretofore been done upon it, but wing-dams will be constructed this season.

Salem, the capital of Oregon, is 45 miles below Corvallis, and about 58 miles above the falls at Oregon City.

The first obstruction below Salem occurs at

M'CLOSKEY'S CHUTE,

nine miles distant. The river here divides into two principal channels, the eastern and western. The latter, after losing a large portion of its volume through an arm which leaves it a short distance from its head, spreads over a shallow bar, and the difficulty occurs at that point. Although the volume of the east channel, which is the straighter and must eventually be the main one, has increased somewhat within the last two years, still, as yet, the western carries by far the greater amount of water, and will be used probably for the next two years. As the snag-boat was being towed up the river, it was left here for a day or two and raked the channel, improving it somewhat, and showing what can be done if the boat should be furnished with sufficient power. During the present season wing-dams will be constructed here, which it is hoped will assist materially in sluicing a channel through the bar.

LONE TREE BAR,

eleven miles below Salem, gave a great deal of trouble previous to the fall of 1875. The river is 900 feet wide during ordinary stages, and 400 feet during low water; a wing-dam 1,430 feet long was constructed, under the supervision of my predecessor, which increased the depth on the bar from 18 to 36 inches; the dam was somewhat injured by the freshets of the winters of 1875–'76 and 1876–'77, and will be repaired during the present season.

GERVAIS SLOUGH,

about 18 miles below Salem, is now the only channel at low water, the crooked arm formerly the principal channel, known as Biterman's Bend, having become closed by drift and gravel-bars. During the past winter the floods stripped the vegetation from the lower end of the island, and caused a great deal of erosion at the same point; the next high water will probably complete the removal of this tongue of land, and greatly improve the river here.

BENNETT'S DREAD SLOUGH.

This slough is 22 miles below Salem; the volume of water passing through it is more than triple that of two years since, the minimum depth having increased from 6 to 24 inches; erosion of the bottom is progressing so rapidly that in a year or two more this will probably be the steamboat-channel; the change is due partly to the removal of snags, and partly to the dam constructed at Union Bar in 1875, whereby a greater volume of water passes down the slough; should it become the main channel, as is expected, 1,800 feet in distance will be saved and two difficult bars, "Union" and "Bennett's Dread," avoided. At

CAREY'S BEND,

thirty-six miles below Salem, the channel is more direct than it was last year, and it is probable no work except the removal of snags will be required.

POLALLEY BAR,

fifty-three miles below Salem, gives trouble this season; there are two channels, one in the middle of the river, the other along the west side; two minor channels leading from the main stream above the bar will be closed this season, and a wing-dam constructed so as to deepen the channel in the middle of the river.

A short distance below Polalley Bar basaltic rock again appears, and we find

BISSELL'S ROCK.

The removal of about 100 yards of rock would greatly improve the channel here; hitherto buoys have been located on the rocks, but all have been carried away; new ones have been made which will be placed in position during the present season.

Just below Rock Island, and about 3 miles above Oregon City, we find

DOVE'S ROCK,

a dangerous obstacle at certain stages of the river. This rock is nearly level, and stands about 6 inches on an average out of water, at the lowest stage, but at all times when it is covered with from 1 to 5 feet water the current sweeps over it with such force as to make it very difficult for descending steamers to make the sharp bend in the channel necessary to avoid it; one steamer has been wrecked here, and others injured; at low-water and during floods there is no trouble. I think it best here to widen and straighten the channel so that steamers descending will pass between Dove's Rock and the ledge to the right of it, instead of making the sharp turn now necessary to pass to the left of it;

a channel 75 feet wide can be obtained by removing about 300 cubic yards of rock, which can be blown off into deep water, and the channel raked.

The foregoing completes the list of impediments to navigation between Corvallis and Oregon City.

A careful observation of the river during its lowest stage for the past two years has shown how the obstructions at the gravel-bars occur; take for example McCloskey's Chute, 9 miles below Salem, which always gives trouble during the early part of the season. During the higher stages, the depth of water and the velocity of the current are nearly uniform all over the bar, the small irregularities not affecting sensibly the general flow of the current; but by the time the water has nearly reached its lowest stage, the surface of the bar presents several dry ridges, separated by shallow channels, neither of them deep enough to be navigable; erosion continues most rapidly where the gravel is finest, and here the volume and current increase, the other channels being in proportion, until nearly the whole body of the river passes through one channel, after which there is plenty of water for the rest of the season.

The first flood, however, fills up the new channel, and every season the two processes are repeated from one to three months, each spring and summer being consumed in forming a new channel, navigation during this period being seriously interrupted. A small steamer provided with a scraper and pile-driver could in a few days open each of these channels, and the current following the scraper would keep them open throughout the season.

OPERATIONS DURING THE FISCAL YEAR.

Work has been in progress during the fiscal year, constructing wing-dams and removing rocks under contract, and removing trees, stumps, and snags with the United States snag-boat. The work done under contract in the summers of 1876 and 1877 has been as follows:

Name of locality.	Distance from Portland, in miles.	Cubic yards of rock excavated.	Total length of dams built, linear feet.	Former depth of the steamboat-channel.	Present depth of the steamboat-channel.
				Inches.	*Inches.*
Half-Moon Bend, upper bar	110½	......	727	22	51
Half-Moon Bend, lower bar	110	......	189	24	(*)
Bower's Bar	107	......	423	42	54
Pine-tree Bar	101	......	583	18	48
Upper Fickel's Bar	95½	......	553	36	48
Black-Dog Slough	95½	......	331	Cut off	....
Lower Fickel's Bar	95	......	190	18	53
Above Buena Vista Bar	91	......	230	Cut off	....
Buena Vista Bar	90½	......	750	20	36
Long Crossing Bar	88	......	756	24	54
Humphrey's Rocks	84	47	......	22	36
Rocky Rapid	76	24½	......	36	54
Total	......	71½	4,732	....	....

(*) Dam built in June, 1877.

The two last columns show the actual increase of depth gained by the improvements at all bars, except Buena Vista and Lower Fickel's, where it is much greater, the channel at these localities having been entirely

changed, crossing the bars at points where formerly there was from 6 to 12 inches of water only. The total work under contract consisted, therefore, in constructing 4,732 feet of dams, and excavating 71¼ cubic yards of rock.

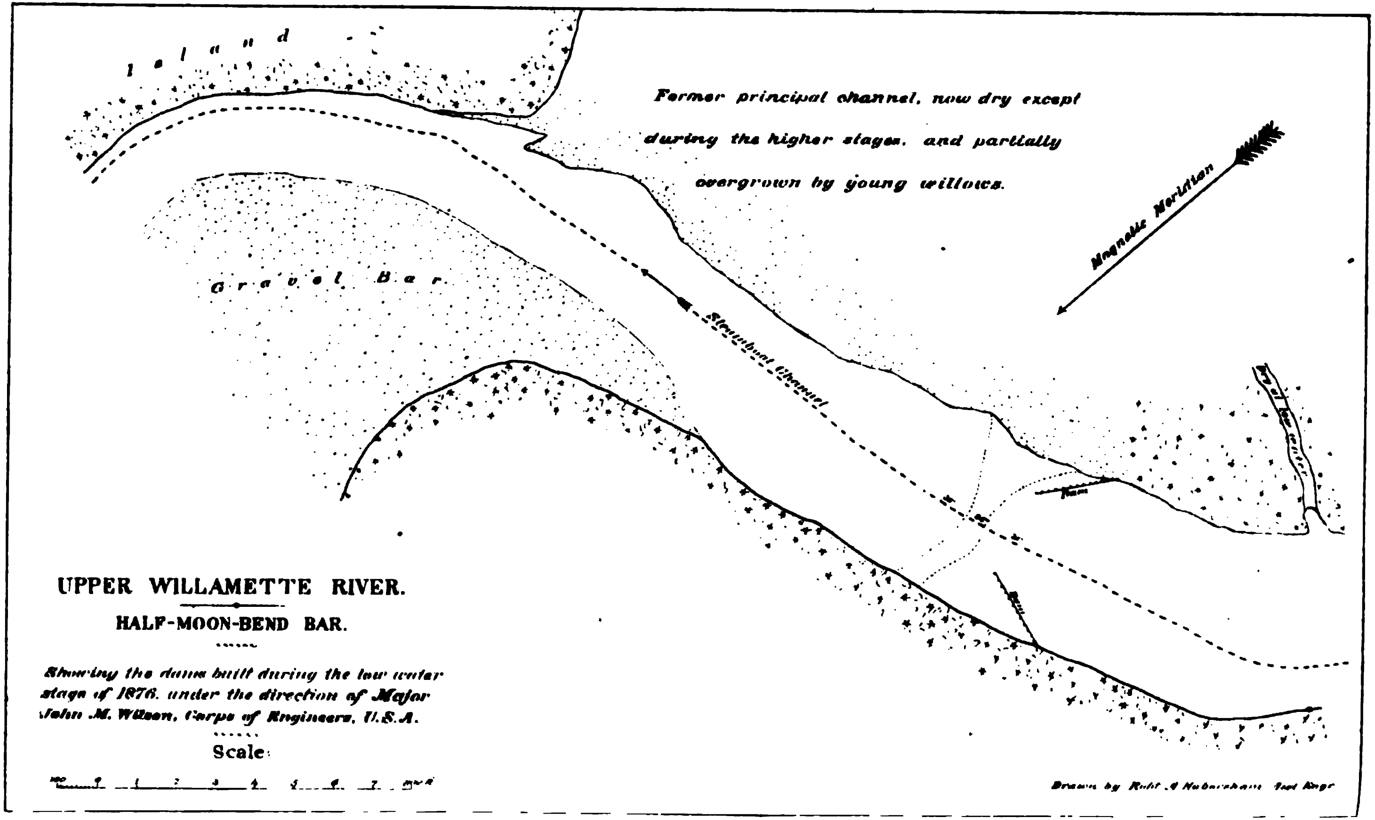
THE UNITED STATES SNAG-BOAT.

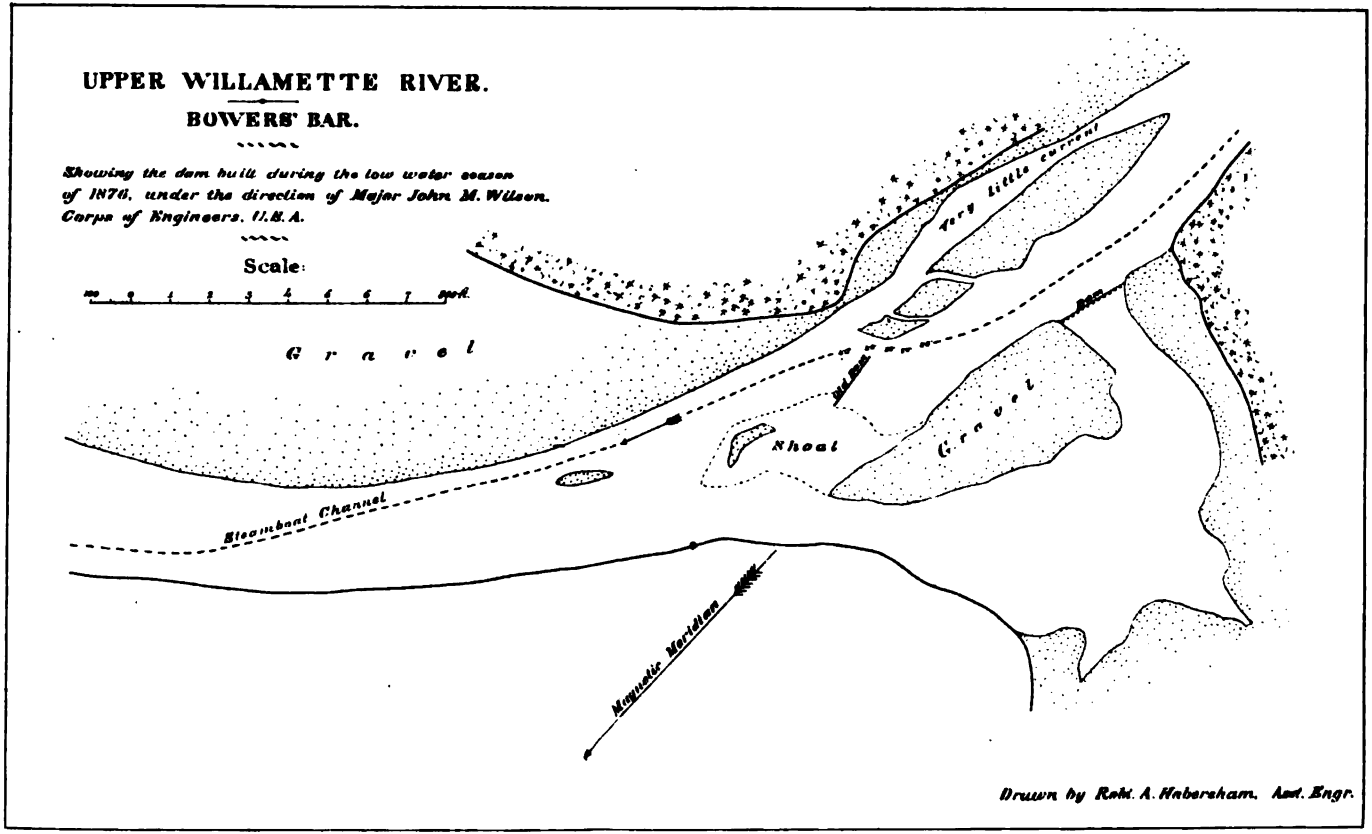
The opening of the fiscal year found the snag-boat engaged near what is known as the "Turntable" in the Centennial Slough; a large quantity of drift had accumulated here, so thick that, in the words of the master of the snag-boat, "it was almost as bad as going through thick woods." The boat was continually engaged on the river until November 10, between Peoria and Oregon City, and on that day was laid up for the season on account of high water. During this period 552 trees, logs, roots, &c., were removed from the vicinity of various localities, as follows:

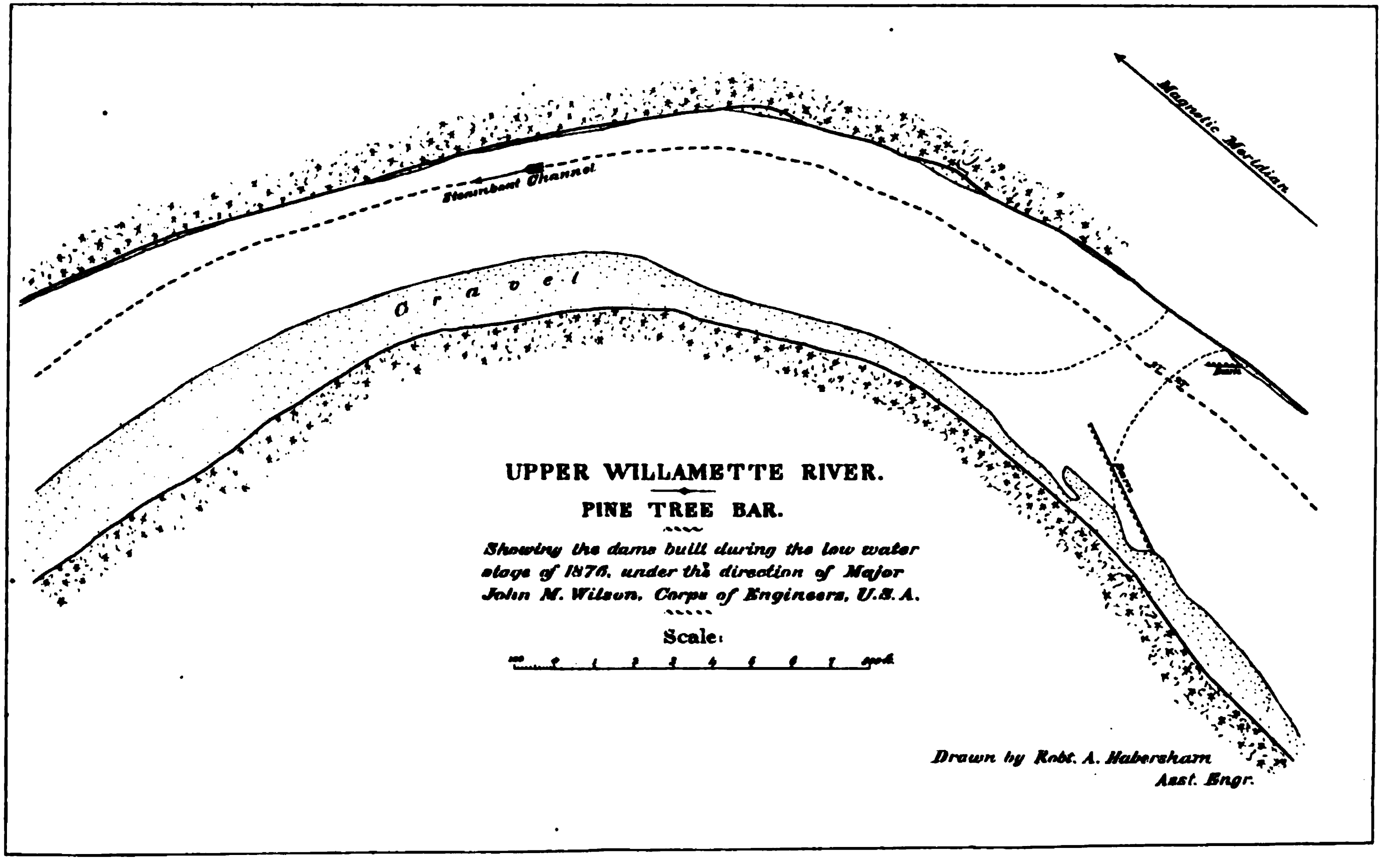
Centennial Slough	34
Foot of Palmer's Prairie	36
Hogue's Slough and Corvallis	195
Half-Moon Bend and Bower's Bar	107
Buena Vista	50
Eola Slough	50
Mouth of the Luckiamute	32
Independence and Gervais Slough	38
Below Salem	10
Total	552

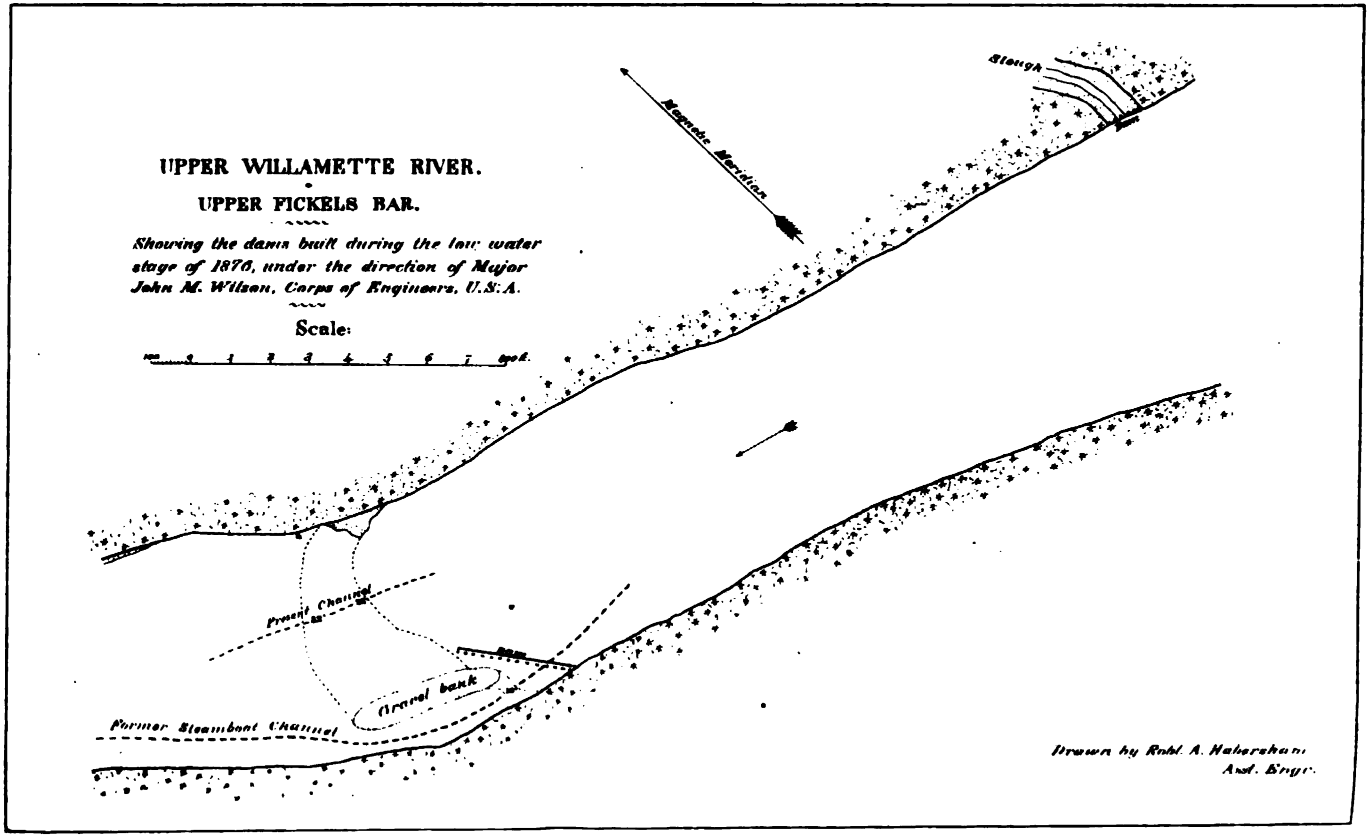
Many of these were enormous trees, necessitating blasting with giant powder before they could be removed. In November, the river being too high for work of removing snags, the boat was sent to the assistance of the wrecked steamer Bonanza, and succeeded in saving her when she had been almost given up as a total loss; the services of the crew while engaged upon this work were paid for by the owners of the steamboat, the United States being at no expense in the case.

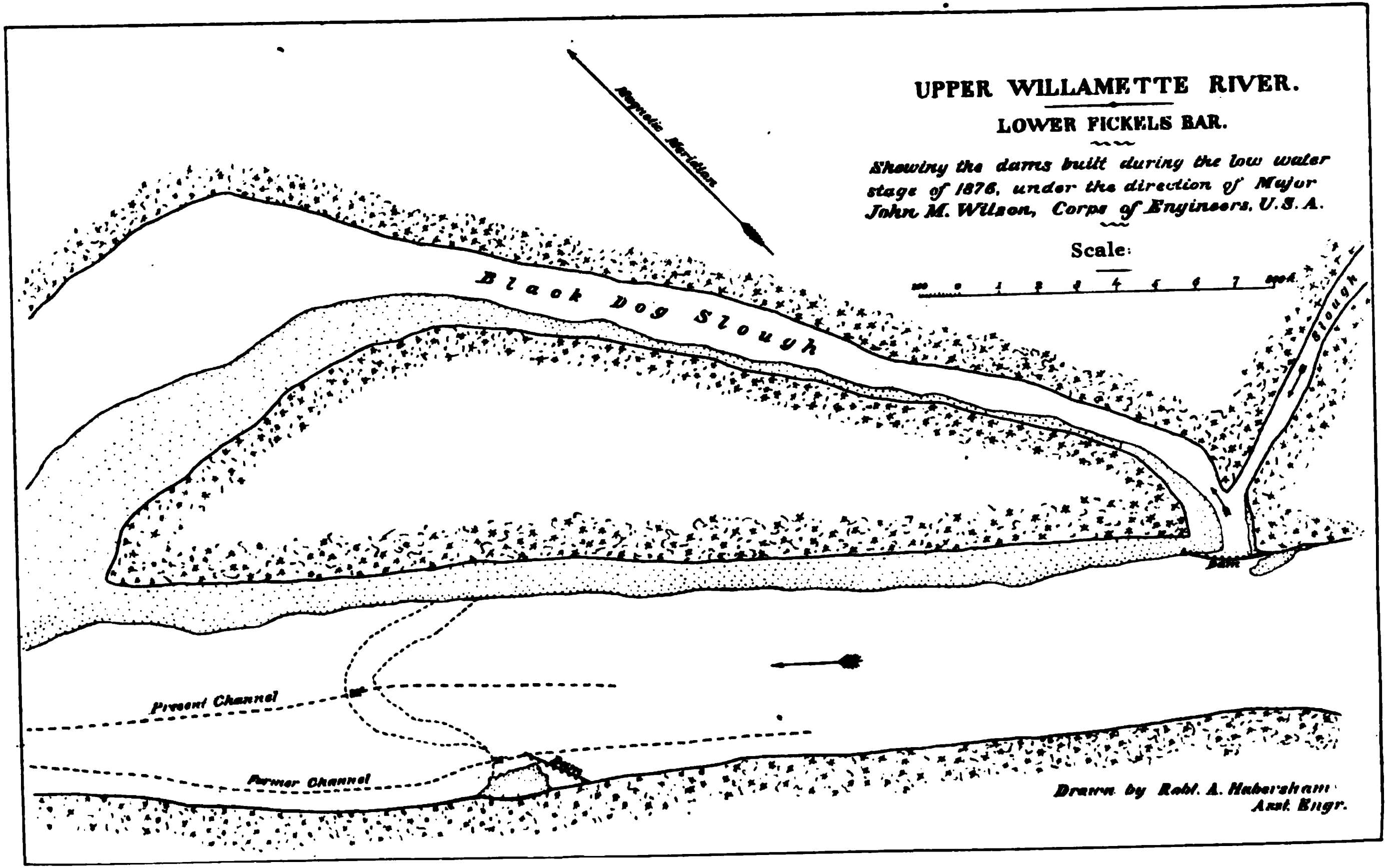
After the close of the season, the snag-boat was beached at Portland, and an examination of her hull showed it to be so badly decayed as to render a new one necessary. By authority of the Chief of Engineers, an agreement was made for the construction of a new hull of very light draught on plans prepared in this office, the builder to receive the old hull and $1,800; the work was commenced early in March, and by April 30 the new snag-boat Corvallis was completed, the machinery and the upper works having been transferred to her from the old one. On May 1 the boat was put in commission, and early in the month towed up the Willamette to the vicinity of Peoria, from whence she dropped down stream, removing snags as she descended. At the Centennial Slough, last winter's flood had brought down a large quantity of drift, which had formed a jam about 1,200 feet below the head, filling the steamboat-channel and forming an almost solid raft from the point of obstruction to the head of the slough; beside this, the river for about 1,000 feet above the slough was almost closed by drift; the boat cleared a channel through this about 100 feet wide, and at the close of the fiscal year was at work in the vicinity of Corvallis. During this period 349 snags, roots, trees, &c., were removed, making a total of 901 removed during the fiscal year. During the present season it is proposed to continue operations, removing snags, trees, &c., from the channel, and to construct about 4,000 linear feet of wing-dams at Buena Vista Bar, Eola Bar, McCloskey's Chute, Lone-tree Bar, and Polalley Bar. Should improvements be needed at other bars, as we descend the river, they will be made.

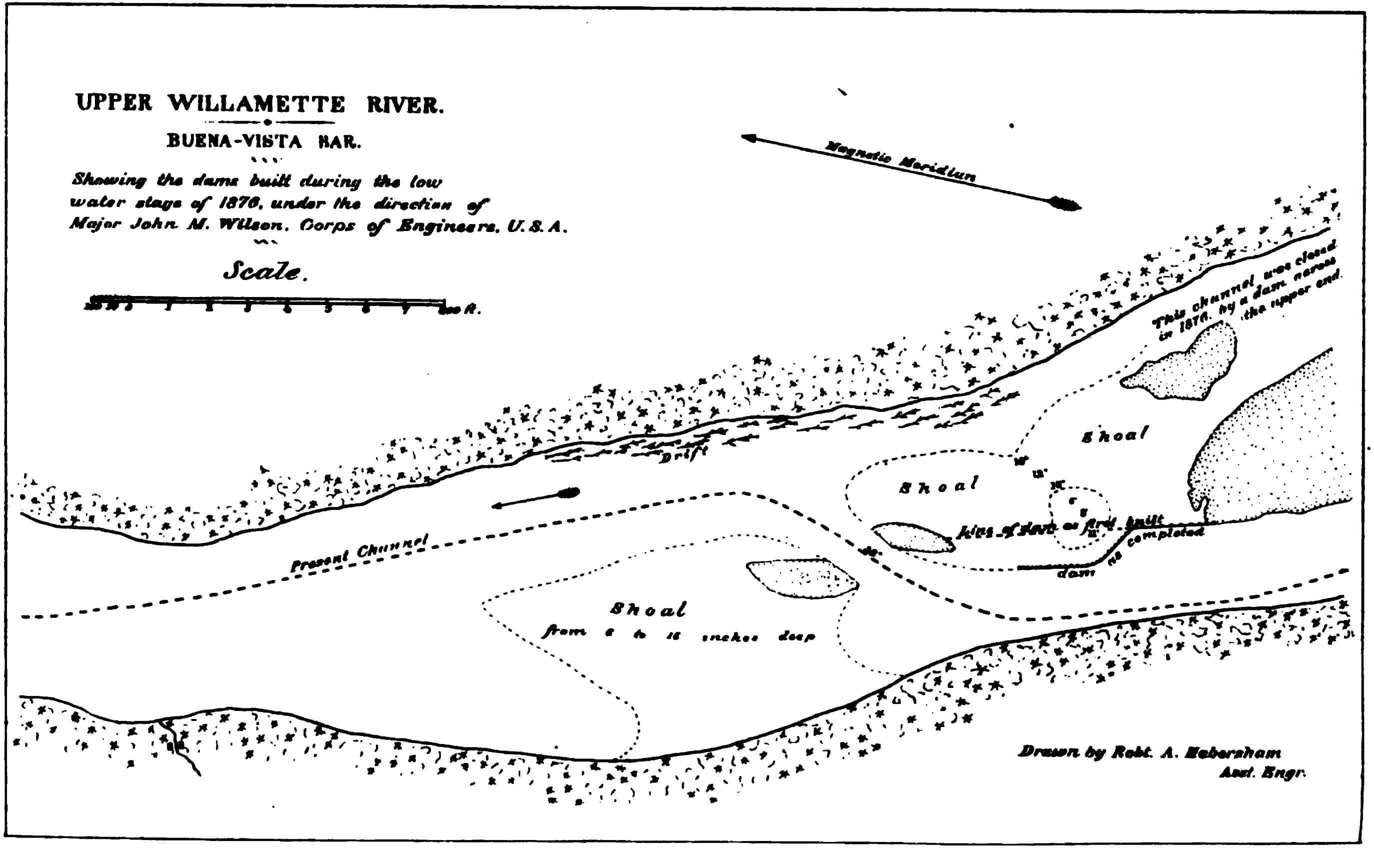

Island
Gravel Bar
Former principal channel, now dry except
during the higher stages, and partially
overgrown by young willows.
Magnetic Meridian
Steamboat Channel
Dam
Dam
UPPER WILLAMETTE RIVER.
HALF-MOON-BEND BAR.
Showing the dams built during the low water
stage of 1876, under the direction of Major
John M. Wilson, Corps of Engineers, U.S.A.
Scale
Drawn by Robt. A Habersham Asst Engr

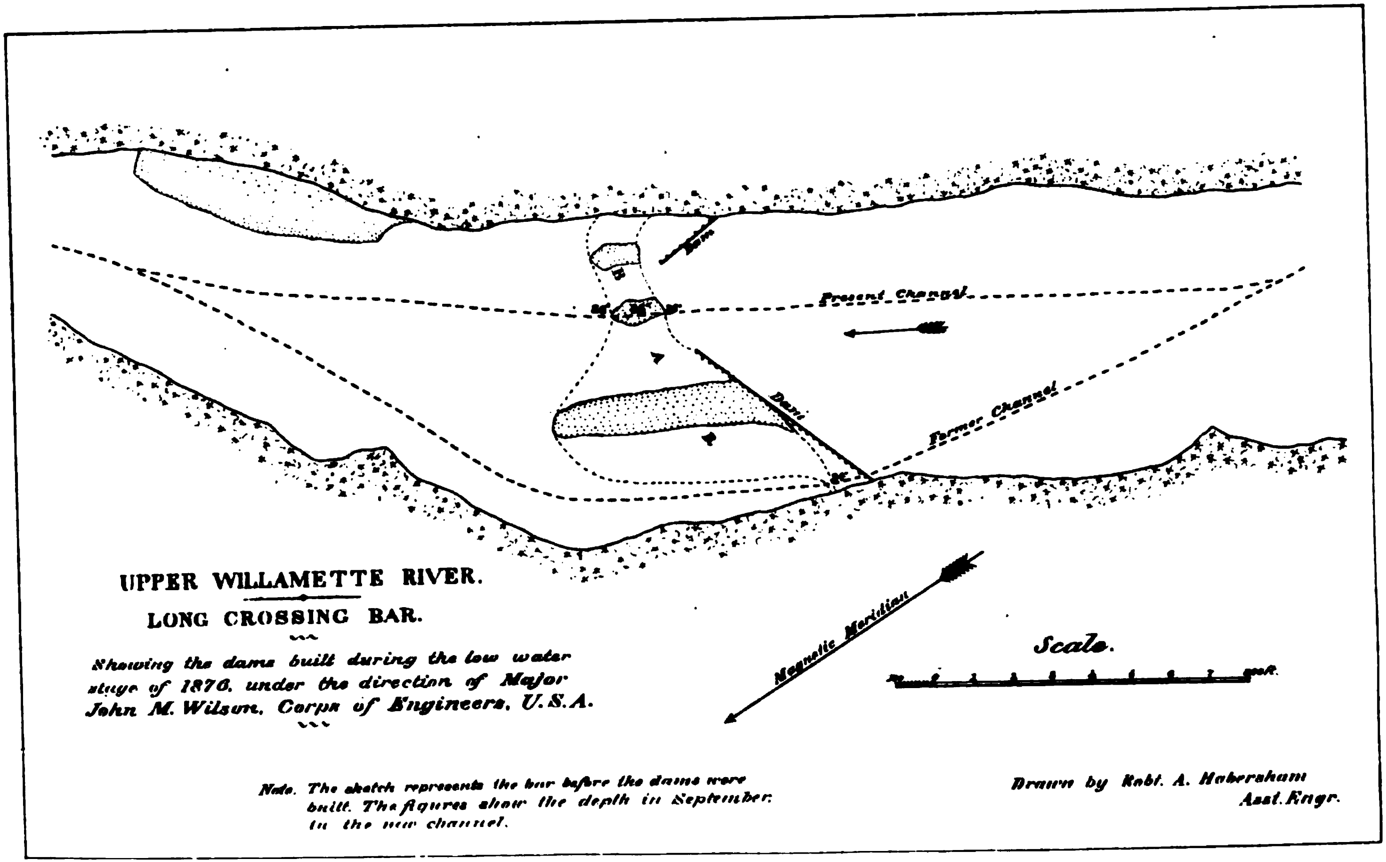

UPPER WILLAMETTE RIVER.
BOWERS' BAR.
Showing the dam built during the low water season of 1876, under the direction of Major John M. Wilson. Corps of Engineers. U.S.A.
Scale:
Gravel
Very little current
Shoal
Gravel
Steamboat Channel
Magnetic Meridian
Drawn by Robt. A. Habersham. Asst. Engr.

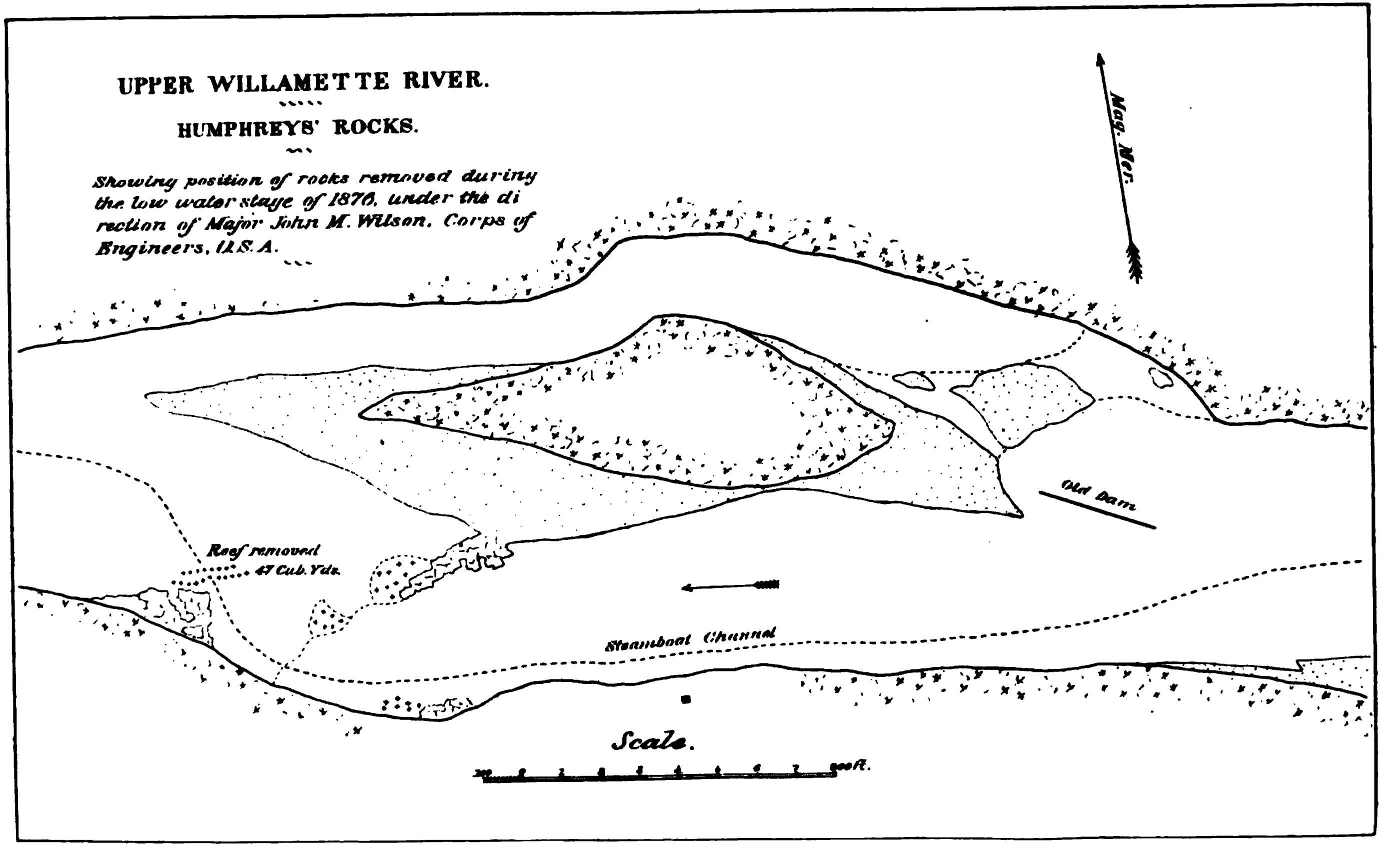

Magnetic Meridian
Steamboat Channel
Gravel
UPPER WILLAMETTE RIVER.
PINE TREE BAR.
Showing the dams built during the low water stage of 1876, under the direction of Major John M. Wilson, Corps of Engineers, U.S.A.
Scale:
Drawn by Robt. A. Habersham Asst. Engr.

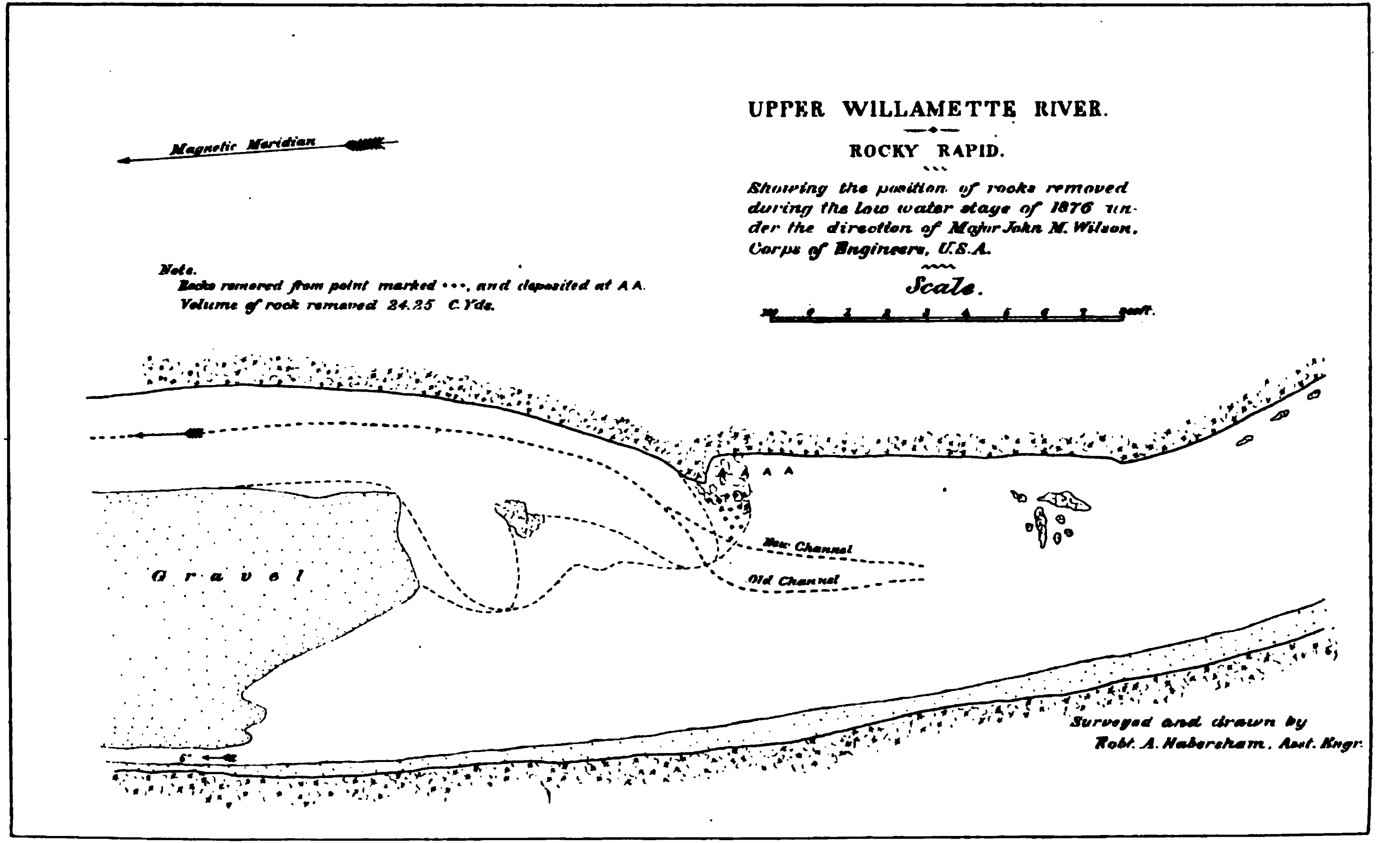

UPPER WILLAMETTE RIVER.
UPPER FICKELS BAR.
Showing the dams built during the low water stage of 1876, under the direction of Major John M. Wilson, Corps of Engineers, U.S.A.
Scale:
Magnetic Meridian
Slough
Dam
Present Channel
Gravel bank
Former Steamboat Channel
Drawn by Robt. A. Habersham
Asst. Engr.


UPPER WILLAMETTE RIVER.
LOWER FICKELS BAR.
Shewing the dams built during the low water stage of 1876, under the direction of Major John M. Wilson, Corps of Engineers, U.S.A.
Scale:
Magnetic Meridian
Black Dog Slough
Slough
Dam
Present Channel
Former Channel
Drawn by Robt. A. Habersham Asst. Engr.


UPPER WILLAMETTE RIVER.
BUENA-VISTA BAR.
Showing the dams built during the low water stage of 1876, under the direction of Major John M. Wilson, Corps of Engineers, U.S.A.
Scale.
ft.
Magnetic Meridian
This channel was closed in 1876, by a dam across the upper end.
Drift
Present Channel
Shoal
Shoal
Shoal
from 6 to 18 inches deep
line of dam as first built
dam as completed
Drawn by Robt. A. Habersham
Asst. Engr.


UPPER WILLAMETTE RIVER.
LONG CROSSING BAR.
Showing the dams built during the low water stage of 1876, under the direction of Major John M. Wilson, Corps of Engineers, U.S.A.
Present Channel
Former Channel
Dam
Dam
Magnetic Meridian
Scale.
Note. The sketch represents the bar before the dams were built. The figures show the depth in September in the new channel.
Drawn by Robt. A. Habersham Asst. Engr.


UPPER WILLAMETTE RIVER.
HUMPHREYS' ROCKS.
Showing position of rocks removed during the low water stage of 1876, under the direction of Major John M. Wilson, Corps of Engineers, U.S.A.
Mag. Mer.
Old Dam
Reef removed 47 Cub. Yds.
Steamboat Channel
Scale.
ft.


UPPER WILLAMETTE RIVER.
ROCKY RAPID.
Showing the position of rocks removed during the low water stage of 1876 under the direction of Major John M. Wilson, Corps of Engineers, U.S.A.
Scale.
Magnetic Meridian
Note.
Rocks removed from point marked ∴, and deposited at A A.
Volume of rock removed 24.25 C.Yds.
A A
New Channel
Old Channel
Gravel
Surveyed and drawn by
Robt. A. Habersham, Asst. Engr.

The project now presented consists of the following:

To build 6,000 feet of cut-off dams and 8,000 feet of wing-dams, and construct a snag-boat with scraper and pile-driver for work above Corvallis; to add propelling power, scraper, and pile-driver to the present snag-boat for work below Corvallis; to remove portions of Bissel's and Dove's Rocks above Oregon City, and to make a complete survey between Corvallis and Portland, a distance of 114 miles. The estimated cost of this project is as follows:

6,000 feet of cut-off dam, at $3	$18,000 00
8,000 feet of wing-dam, at $2	16,000 00
New snag-boat above Corvallis	12,000 00
Improvement of snag-boat below Corvallis	6,500 00
Survey between Corvallis and Portland, 114 miles	12,000 00
Maintenance of two snag-boats, each six months, at $900 per month, each $5,400	10,800 00
Removing 100 cubic yards Bissel's Rock, at $9	900 00
Removing 300 cubic yards Dove's Rock, at $5	1,500 00
Contingencies and engineering	2,300 00
Total	80,000 00

An annual appropriation of about $12,000 will be required to keep the snag-boats in order and run them.

The following statistics required by the act of June 23, 1866, are respectfully submitted:

The appropriations for this work have been as follows:

Act of March 3, 1871	$16,000 00
Act of March 3, 1873	3,000 00
Act of June 23, 1874	7,500 00
Act of March 3, 1875	25,000 00
Act of August 14, 1876	20,000 00
	71,500 00

Of this amount $57,258.22 has been expended to date. The project now submitted calls for the construction of certain dams, and building, and maintenance for one year, of snag-boats at a cost of $80,000; of this amount $50,000 can be profitably expended during the next fiscal year.

This river is in the collection-district of the Willamette; Portland, Oreg., is the nearest port of entry, and the nearest light-houses and works of defense are at the mouth of the Columbia River.

The amount of revenue collected at the port of Portland, Oreg., during the eleven months ending June 1, 1877, was $125,317; the value of the imports was $388,476, and of the exports $2,509,159; 177 vessels with an aggregate tonnage of 152,961 tons entered, and 153 with a tonnage of 144,296 tons cleared during the same period. There are four companies now running boats on the Upper Willamette River, as follows: the Willamette Transportation and Lock Company, U. B. Scott & Co., the owners of the S. T. Church, and the owners of the McMennville.

During the eleven months from July 1, 1876, to June 1, 1877, the Willamette Transportation and Lock Company carried through their locks at Oregon City the following:

Seven thousand six hundred and seventy-seven up-passengers; 7,141 down-passengers; 6,098 tons of up-freight; 57,452 tons of down-freight; of the latter, 49,699 tons was wheat and flour.

The steamer S. T. Church ran only a few weeks during the year, and carried the following:

One hundred and twenty-five passengers up-stream; 150 passengers down-stream; 100 tons of up-freight; 3,000 tons of down-freight; of the latter, 2,900 tons was wheat.

I was unable to procure information from the other companies in reference to the amount of business done by them.

The commerce of this river is increasing, but I cannot give an estimate of the amount that will be benefited by the completion of this work;

the navigation to be improved extends from Portland to Eugene City, a distance of 172 miles.

Abstracts of proposals and contracts, a statement of funds, and 9 charts, showing location of work done during the year, are transmitted herewith.

Money statement.

July 1, 1876, amount available	$8,038 25	
Amount appropriated by act approved August 14, 1876	20,000 00	
		$28,038 25
July 1, 1877, amount expended during fiscal year	13,796 47	
July 1, 1877, outstanding liabilities	2,157 45	
		15,953 92
July 1, 1877, amount available		12,084 33
Amount (estimated) required for completion of existing project		80,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.		50,000 00

Abstract of proposals for building wing-dams in the Upper Willamette River, Oregon, opened by Maj. John M. Wilson, Corps of Engineers, February 8, 1877.

No.	Names and residences of bidders.	5,000 feet wing-dams, more or less, per linear foot.	Remarks.
1	Grant & Stone, The Dalles, Oreg	$1 90	Contract awarded.
2	Joseph Paquet, Oregon City, Oreg	2 40	No guarantee accompanying proposal. Bid thrown out.
3	Peter Paquet, Oregon City, Oreg	2 40	

Abstract of contracts for the improvement of the Upper Willamette River, Oregon, in force during the fiscal year ending June 30, 1877.

Number.	Names and residences of contractors.	Date of contract.	Class I.	Class II.	Class III.
			8,000 feet of wing-dams, more or less, per linear foot.	Removal of rock at certain points, per cubic yard.	5,000 feet of wing-dams, more or less, per linear foot.
1	Peter and F. X. Paquet, Oregon City, Oreg	Sept. 6, 1875	$1 80	$15 00	
2	Grant & Stone, The Dalles, Oreg	Feb. 26, 1877			$1 90

JJ 3.

IMPROVEMENT OF THE UPPER COLUMBIA AND SNAKE RIVERS, OREGON AND WASHINGTON TERRITORY.

The portions of these rivers to be considered, and for which appropriations have heretofore been made, consist of the Columbia River from Celilo, 240 miles above its mouth, to its junction with the Snake River, a distance of 117 miles, and the Snake River from its mouth to Lewiston, a distance of 149 miles, making a total length of 266 miles to be improved. Within this stretch of river-navigation there are 25 rapids, nearly all of which will require improvement before the river can be

navigated with safety, and many of which require immediate work in order that steamers may ascend to Lewiston, Idaho, during the low-water season. A careful reconnaissance of all these rapids has been made by myself, and surveys have been made of some of them under my direction during the past fiscal year, and I am now able to give a general description of them, and to present a project for the improvement of these rivers from Celilo, Oreg., to Lewiston, Idaho.

THE COLUMBIA RIVER.

Starting from Celilo, the terminus of the railroad around the Dalles of the Columbia, the first difficulty is encountered at

FIVE-MILE RAPID,

about that distance above. This place requires skillful navigation, but is not considered by pilots very dangerous. To improve it would require a large outlay owing to the length and massive character of the rock. No work is proposed here at present.

LOWER JOHN DAY'S RAPID

is 10 miles further up. At this locality two rocks in the channel, estimated to contain about 100 cubic yards, require removal. One and one-half miles above is

MIDDLE JOHN DAY'S RAPID.

A rock which formerly greatly obstructed the channel here was removed in 1874, and no further work is required at present.

UPPER JOHN DAY'S RAPID

is about a mile above. There are two channels here, one on the north and one on the south side. The improvement of this locality is of first-class importance, and the removal of about 400 cubic yards of rock from the channel is necessary to render it navigable without danger.

INDIAN RAPID,

three miles above, does not require attention at present. At some future day it may be deemed necessary to remove some rock lying at the head of the rapids.

SQUALLY HOOK RAPID

is next in order, and 3 miles above. The lower portion of this rapid has been much improved during the past season. At a low stage of the river loaded boats descending will be obliged to drift around the bend which the channel makes, but this can be done with safety and but little delay, and no trouble will be had by boats ascending. Any further improvement will require the removal of a large quantity of rock, and is not recommended at present.

Four miles above is

ROCK CREEK RAPID,

a place where there are three channels. The main one, which should be used for running down stream, is obstructed by a single rock in mid-

channel; this channel is on the south side, and has too swift a current for running up stream. The middle channel is used by boats ascending, and is good for that purpose, but has too sharp a bend for coming down. The north channel is used at present for boats descending, but is narrow and very shoal at low-water. The rocks to be removed here are the one in the main channel, one which divides the middle from the north channel, and a small one on the lower side of the middle channel, aggregating in all about 100 cubic yards.

OWYHEE RAPID

is 10 miles above. A large rock was removed from the channel here during the winter of 1876–'77, and, although the rapid requires skillful navigation, no further work is deemed necessary at present.

Twenty-three miles above we find

CANOE ENCAMPMENT RAPID.

No material difficulty is experienced in passing this by daylight, and no work is deemed necessary at present.

DEVIL'S BEND,

20 miles beyond, is a difficult and dangerous place, requiring improvement; five rocks should be removed from the channel here, aggregating in all about 150 cubic yards. Four miles above Devil's Bend is the town of Umatilla, from whence a line of stages run, crossing the Blue Mountains and connecting, via Pendleton, Baker City, and Boise, with the Central Pacific Railroad at Kelton, Utah. Six miles above Umatilla we find the

LOWER UMATILLA RAPID.

The channel here is very crooked and its improvement of primary importance; at least 225 cubic yards of rock should be removed; the work can be easily accomplished, as the current at the stage at which it should be done is comparatively slack, not exceeding 4 miles an hour.

A short distance above is

MIDDLE UMATILLA RAPID,

where the channel is difficult and dangerous to navigate; two rocks lie about 60 feet apart, one on each side of the channel at the head of the rapid; the one on the left ascending should be removed; it is about 80 feet long and 10 feet wide, with a depth of about 1½ feet upon it at low-water; there are two other rocks lying directly below it, at a distance of about 200 and 300 feet respectively, both on the same side of the channel, which require removal; the total to be removed from this rapid is about 150 cubic yards.

UPPER UMATILLA RAPID

is a short distance farther up; work has been in progress here for the past three years, improving the high-water channel so as to render it available at all stages of the river; it has now a width of 70 feet at low-water, which should be increased to at least 100 feet; the former low-

water channel is long, crooked, difficult, and dangerous, expecially with a large boat, and a variation of 15 or 20 feet either way from the narrow channel would result in disaster. To complete the high-water channel so as to render it available at all stages of the river will require the removal of about 300 cubic yards of rock in addition to the work now under contract. About 10 miles above is a locality known as

MILL ROCK.

This place is difficult to pass after dark, and requires skillful navigation at all times. It is not, however, considered dangerous by pilots, although in descending with a well-laden boat very careful handling is required. No work is proposed here at present.

The town of Wallula is located 9 miles above. It is the terminus of the Walla-Walla and Columbia River Railroad, a narrow-gauge road, 32 miles long. The only remaining obstruction between Mill Rock and the mouth of the Snake is

HOMLY RAPID,

6 miles above Wallula. The larger and more serious obstacles were removed from this rapid last year, but the river is shoal and bowlders are liable to accumulate, being brought down by floating masses of ice.

To open this channel so as to render it safe at all times will require the removal of about 75 cubic yards of rock. From Homly Rapid the river presents a good channel to the mouth of the Snake.

THE SNAKE RIVER.

Entering this river we find some bowlders a short distance above the mouth which lie in the deeper portion of the channel, and although their removal is not immediately necessary, still at some future day it will be found advantageous to take out at least three of them, and thus permit steamers to pass over a deeper channel than they now use. The first serious obstacle is encountered at

FIVE-MILE RAPID,

situated about that distance above the mouth. This calls most imperatively for improvement, and is not only dangerous, but almost impassable at low-water. There are four rocks requiring removal, aggregating in all about 350 cubic yards.

Five miles above is a locality known as

THREE ISLANDS.

About 60 yards of rock could be removed here with advantage, but as it is not deemed absolutely necessary, it is not recommended for the present.

FISH-HOOK RAPID,

16 miles from the mouth of the Snake, is about 1 mile in length and consists of three belts or reefs. One rock at the head imperatively demands immediate removal, and work is required on each of the reefs, aggregating about 300 cubic yards in all.

The next obstruction is at

LONG CROSSING BAR,

about 15 miles above Fish-Hook Rapid. The channel here is shoal, with a bottom of rock and large bowlders. Two rocks which stand in the channel opposite to about the middle of the island should be removed, and some of the bowlders should be taken from the edge of the reef at the upper end. The aggregate amount to be removed here is about 200 cubic yards.

Two miles beyond is

PINE-TREE RAPID,

a very long and dangerous rapid, exceedingly difficult to navigate except at high-water. While endeavoring to pass this in the autumn of 1876, the steamer upon which I was traveling, although drawing only about 2 feet of water, struck twice and filled four compartments of her hull, and in spite of urgent effort was obliged to return without crossing. The channel, however, was greatly improved during the winter of 1876–'77 by making a cut through the massive reef at the upper end, hitherto impassable at low-water, and removing about fourteen other rocks. Much work is still required here; many bowlders must be removed and the chute through the upper reef widened. The aggregate amount to be taken out is about 650 cubic yards.

MONUMENTAL ROCKS

are about 8 miles above Pine-Tree Rapid. A reef stretches across the river here over which steamers must pass, and at low-water it is a dangerous place. The channel is broad, but crooked and shallow. Some high points of rock on the reef, principally from the right side of the channel ascending, require removal, the aggregate amount being about 250 cubic yards.

FALSE PALOUSE

is about 12 miles farther up. The channel lies between massive rocks and is narrow, but deep and straight. It should be widened by the removal of about 150 cubic yards of rock. Five miles above False Palouse, and nearly opposite the mouth of Palouse River, is

PALOUSE RAPID,

a wild, dangerous place, where the river, at low-water, dashes through a narrow channel, forming a natural canal through the rocks; the current is rapid, and navigation dangerous; at least five rocks, aggregating about 300 cubic yards, urgently call for removal at this place.

About 10 miles above Palouse we find,

TEXAS RAPID.

The river here has the strongest current and greatest fall in a short distance of any place below Lewiston. The rapid is about 1 mile long, and the fall is said to be over 15 feet. No really distinct channel exists at low-water, the river being so much divided by ledges of rock; one line, more distinct than the rest, will be selected for widening, and its improvement will require the removal of about 700 cubic yards of rock.

From Texas Rapid to Lewiston the river is in a favorable condition for navigation, with a good gravel bottom, although shoal, and is tolerably

free from obstructions, except at a point about 4 miles below Lewiston, where several rocks in a bend of the channel may ultimately require removal. This is, however, not immediately necessary. At

STEPTOE RAPID,

20 miles below Lewiston, there is a gravel bar where the construction of a wing dam may eventually be necessary. There are numerous other gravel bars, but they do not give much trouble.

The foregoing shows the various obstructions to navigation between Celilo and Lewiston. To recapitulate, the work required will be the removal of rocks about as follows:

Upper Columbia River.		Snake River.	
Name of rapid.	Amount.	Name of rapid.	Amount.
	Cub. yds.		*Cub. yds.*
Lower John Day Rapid	100	Five-Mile Rapid	350
Upper John Day Rapid	400	Fish-Hook Rapid	300
Rock Creek Rapid	100	Long Crossing Rapid	200
Devil's Bend Rapid	150	Pine-Tree Rapid	650
Lower Umatilla Rapid	225	Monumental Rocks	250
Middle Umatilla Rapid	150	False Palouse	150
Upper Umatilla Rapid	300	Palouse Rapid	300
Homly Rapid	75	Texas Rapid	700
Total	1,500	Total	2,900

Of the places mentioned there are six demanding immediate improvement on the Snake River, namely, Five-Mile, Fish-Hook, Pine-Tree, Monumental Rocks, Palouse, and Texas Rapids, while on the Columbia additional work is much needed immediately at the Umatilla and John Day's Rapids. Upon the completion of work at the six places named on the Snake, the rivers may be pronounced open to Lewiston, but the navigation of the rapids will still require skillful and careful pilots.

OPERATIONS DURING THE PRESENT FISCAL YEAR.

Owing to the river rising earlier than usual in the spring of 1876, Messrs. Grant & Stone were unable to complete their contract of October 29, 1875, within the time prescribed, and, in accordance with authority from the Chief of Engineers, it was extended until April 1, 1877.

In July, 1876, proposals were invited for removing 200 cubic yards, more or less, of rock from the channel at the Upper Umatilla Rapids, and on August 30, the work was awarded to Mr. J. B. Montgomery, of Portland, Oreg., the lowest bidder, at the rate of $31 per cubic yard.

By the act of Congress approved August 14, 1876, an appropriation of $15,000 was made for the improvement of the Upper Columbia and Snake Rivers, and it was determined to apply it to the improvement of Squally Hook Rapid, Columbia River, and Pine-Tree Rapid, Snake River, and to remove about 100 cubic yards of rock from the former and about 480 yards from the latter. As the season for operations was near at hand, by authority of the Chief of Engineers, instead of advertising, letters were at once addressed to the various contractors who had hitherto bid upon work of this character, requesting them to inform the engineer in charge by November 10, 1876, at what rate per cubic yard they would remove the amounts mentioned from Squally Hook and Pine-Tree Rapids.

Proposals were received from three parties, and the work was awarded to Messrs. Grant & Stone, the lowest bidders, for Squally Hook, at $23, United States currency, per cubic yard, and to Mr. J. B. Montgomery, the lowest bidder, for Pine-Tree Rapid, at $24.75, United States currency, per cubic yard, and contracts were made with these parties accordingly.

Operations were commenced under the contract of October, 1875, of Messrs. Grant & Stone, at

OWYHEE RAPID, COLUMBIA RIVER,

early in December, the contractors having been on hand for two or three weeks previously with their men and plank awaiting the necessary fall in the river. The work to be done at this rapid consisted in the removal, to a depth of 6 feet below dead low-water, of a large rock on the south side of the channel. On December 11 this rock was carefully surveyed, and found to contain 67.57 cubic yards. The work of drilling was at once commenced, and was progressing well when, on the 16th, the contractors, who had met with many misfortunes under their contract, were again subjected to a fearful accident, caused by the explosion of dynamite while being thawed, resulting in the killing of two men who were in the powder-house and the entire demolition of the building. The cause of the accident cannot be explained, as the only men in the building were killed. The man in charge of the powder had had considerable experience in its use, and had been employed by the contractors on that account. Operations were temporarily suspended, but again renewed the latter part of the month, and the removal of the rock completed early in January. The crew and plant were then taken down the river, and work commenced at once at

SQUALLY HOOK RAPID.

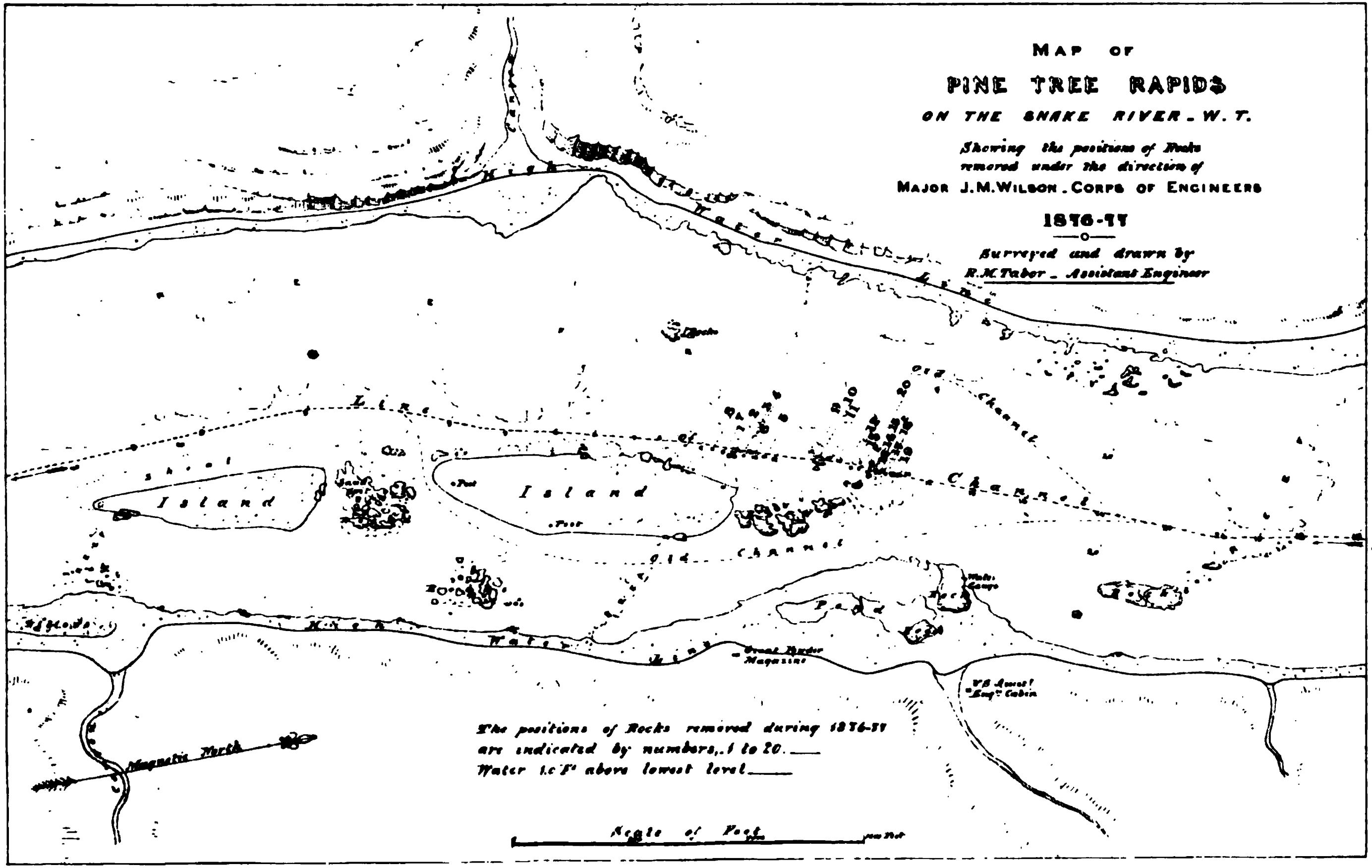
A ledge of rock extending into the channel at this place rendered navigation difficult and dangerous, steamers descending being obliged to drift very close to the ledge. After a careful survey it was determined to apply the remainder of the work to be done under the old contract of Grant & Stone (about 50 yards) and that under their new contract to this locality, and to widen the channel about 40 feet. The work of drilling and blasting was commenced on January 22, 1877, and by the close of February 150.06 cubic yards had been removed, the increased width desired obtained, and, the contracts having been completed, operations were suspended for the season.

The channel here has been greatly improved. Boats descending are, however, still obliged to drift around the bend during low-water, but as this can be done with safety and but slight delay, and, as any further improvement would necessitate the removal of a large quantity of rock, the continuance of work here is not recommended for the present.

The work of improvement at the

UPPER UMATILLA RAPID,

which consisted in widening the high-water channel, was commenced under the contract with Mr. J. B. Montgomery on the 18th of October, 1876. Rocks known as Nos. 18 and 19 were measured, and the work proceeded well, when, on the 24th, the river suddenly rose and rendered it



MAP OF
PINE TREE RAPIDS
ON THE SNAKE RIVER - W. T.
Showing the positions of Rocks
removed under the direction of
MAJOR J.M. WILSON . CORPS OF ENGINEERS
1876-77
Surveyed and drawn by
R.M. Taber - Assistant Engineer
High Water Line
Line of Channel
Old Channel
Island
Island
Pond
Rock
Rocks
Magnetic North
The positions of Rocks removed during 1876-77
are indicated by numbers, 1 to 20.
Water 1.6 Ft above lowest level
Scale of Feet

very difficult to work. Operations were, however, continued until the latter part of November, by which time 50 yards, the greater part of rock No. 18, had been removed. The water being still very high, the contractor asked authority to suspend work until a later date, when the river would be lower, in order to commence upon Pine-Tree Rapid, in the Snake River. This request was granted with the proviso that both contracts should be completed within the allotted time. Work was accordingly suspended, and, after the completion of operations at Pine-Tree Rapid, was renewed in the latter part of February. It was presumed that low-water would continue until the last of March, but the Snake River suddenly rose, raising the Columbia several feet and increasing the velocity of the current at Umatilla Rapid, so that it was impossible to work the drills; the contractor made every effort to continue operations, but finding the river still rising, he suspended work about the middle of March and secured his plant from danger for the season. In consideration of the circumstances, the time of completion of this contract was extended until February 28, 1878.

PINE TREE RAPID, SNAKE RIVER.

A careful reconnaissance of this rapid, made by the engineer in charge during low-water in the latter part of September, 1876, showed it to be impassable at that stage for steamers drawing over 2 feet water. The channel used even at a much higher stage was narrow, crooked, intricate, and filled with hidden rocks. It was determined to open a straight one through the rapid, which could be navigated at all seasons of the year. To do this required the removal of numerous rocks and the opening of a chûte through the ledge at the head. Navigation on the Snake having been suspended for the season, the contractor's agent started on November 25, 1876, from Wallula, Washington Territory, for Pine-Tree Rapid, Snake River, a distance of about 43 miles, with the crew and plant, the scow being towed by mules on shore. Assistant Engineer R. M. Tabor started across the country about the last of November, following the trail to the rapid, which he reached after two days' ride, spending one night without shelter on the banks of the Snake. The scow reached Pine Tree on December 2, after a hard trip, during which the party had to contend with ice and snow. Shanties were at once erected, and preparations made for a winter campaign. The nearest post-office was at Wallula, about 30 miles distant by land, and the nearest ranch from which supplies could be obtained was that of Mr. Marion on the Touchét River, about 22 miles distant. With the assistance of Capt. E. W. Baughman, a thoroughly efficient and reliable pilot of many years' experience on the Snake River, the worst rocks were at once located, and drilling and blasting commenced. Operations were continued until February 22, 1877, being more or less interrupted by heavy floating ice, and on that day were suspended, 477.57 cubic yards of rock having been removed, and the contract completed.

The work done comprised the removal of 20 rocks, excavated from a length of 850 feet of the worst portion of the channel. Seven of these rocks being a portion of the ledge at the head of the rapid, the channel through which is now 49 feet wide and well marked by the current.

The actual amount of rock removed was as follows:

	Cubic yards.		Cubic yards.
Rock No. 1	65.56	Rock No. 4	3.54
Rock No. 2	7.96	Rock No. 5	12.89
Rock No. 3	44.88	Rock No. 6	30.79

	Cubic yards.		Cubic yards.
Rock No. 7	23.71	Rock No. 15	9.77
Rock No. 8	31.41	Rock No. 16	28.54
Rock No. 9	41.40	Rock No. 17	3.64
Rock No. 10	41.79	Rock No. 18	4.99
Rock No. 11	17.56	Rock No. 19	49.51
Rock No. 12	3.86	Rock No. 20	52.45
Rock No. 13	0.87		
Rock No. 14	2.39	Total	477.51

Although much has been done, much yet remains to be accomplished, as the channel, although straight, is still narrow and dangerous; the chûte at the upper end should be widened to at least 80 feet, and all rocks below, for a width of at least 100 feet, should be removed to a depth of 6 feet below the level of the lowest low-water.

The work accomplished, therefore, during the fiscal year consists in the removal of rocks from the rapids, as follows:

	Cubic yards.
COLUMBIA RIVER.	
From Squally Hook Rapid	150.06
From Owyhee Rapid	67.57
From Umatilla Rapid	50.00
SNAKE RIVER.	
From Pine-Tree Rapid	477.51
Total	745.14

Mr. R. M. Tabor, assistant engineer, deserves credit for the energy, care, and attention he has shown in the progress of the work.

During the coming season it is proposed to complete the work at the Upper Umatilla Rapid, under the contract of J. B. Montgomery, by removing 150 cubic yards of rock. The work will be confined to rocks 19, 20, 25, 26, and 27, on the north side of the upper end of the channel. Buoys will be permanently attached to the rocks on each side at the head of the channel. It is hardly necessary for me to again call attention to the necessity of continuing this work, as so much has already been said. The country east of the cascades is rapidly becoming a magnificent wheat-garden, and the export of grain during the coming season will be enormous. If farmers could only be certain of getting their grain to market in the fall, the vicinity of the Snake River would soon be fully settled, and extensive wheat-fields, yielding from 30 to 40 bushels to the acre, would cover the whole country. The population of this section has been greatly increased during the past year, but the fear of not being able to send their crops to market at once, on account of the impossibility of navigating the Snake River Rapids during low-water, has deterred many settlers from locating there.

The following information, required by the act of Congress approved June 23, 1866, is respectfully submitted:

The appropriations for this work have been as follows:

Act of June 10, 1872	$50,000 00
Act of June 23, 1874	20,000 00
Act of March 3, 1875	35,000 00
Act of August 14, 1876	15,000 00
Total	120,000 00

Of this amount $114,249.91 has been expended to date—$101,694.62 on the Columbia River, at John Day's, Squally Hook, Owyhee, Devil's Bend, Umatilla, and Homly Rapids; and $12,555.29 on the Snake River, at Pine-Tree Rapids. The project now submitted calls for the removal

of 1,500 cubic yards of rock from the Columbia River above Celilo, and 2,900 cubic yards from the Snake River, between its mouth and Lewiston, the estimated cost of the whole of which is $132,000. Of this amount $66,000 can be profitably expended during the next fiscal year.

These rivers are in the collection-district of the Willamette; Portland, Oreg., is the nearest port of entry; the nearest light-houses and forts are at the mouth of the Columbia River, but troops garrison the posts of Walla-Walla, about 32 miles from Wallula, and Lapwai, 12 miles from Lewiston.

I am informed that the number of passengers and the amount of freight carried by the Oregon Steam Navigation Company over their portage road at the Cascades during the first eleven months of the present fiscal year, was greatly in excess of the amount transported by them during the same period in the last fiscal year, the excess arising to a great extent from the increased emigration to the vicinity of the Snake River, and the rapid development of the country east of the Cascade Mountains.

The amount of revenue collected at Portland, Oreg., during the eleven months ending June 1, 1877, was $125,317; the value of the imports was $338,476, and that of the exports was $2,509,159.

The number of vessels entering was 177, with an aggregate tonnage of 152,961 tons; the number of vessels clearing was 153, with an aggregate tonnage of 144,296 tons. It is impossible to give an estimate of the amount of commerce that will be benefited by the completion of this work, as it will increase as the country is developed. The navigation improved will cover the whole of the Columbia and Snake Rivers, from Celilo to Lewiston, a distance of 266 miles.

Abstracts of proposals received and contracts made during the year, a statement of funds, and a chart of Pine-Tree Rapid, Snake River, showing rocks excavated during the year, are transmitted herewith.

Money statement.

July 1, 1876, amount available	$16,007 10	
Amount appropriated by act approved August 14, 1876	15,000 00	
		31,007 10
July 1, 1877, amount expended during fiscal year	25,257 01	
July 1, 1877, outstanding liabilities	155 00	
		25,412 01
July 1, 1877, amount available		5,595 09
Amount (estimated) required for completion of existing project		132,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1879.		66,000 00

Abstract of proposals for excavating rock from the Upper Columbia River, Oregon, and Washington Territory, opened by Major John M. Wilson, Corps of Engineers, August 30, 1876.

Number.	Names and residences of bidders.	Excavating 200 cubic yards rock. Price per cubic yard.	Excavating 200 cubic yards rock. Total.	Remarks.
1	J. B. Montgomery, Portland, Oreg	$31 00	$6,200 00	Contract awarded.
2	Grant & Stone, The Dalles, Oreg	31 50	6,300 00	

Abstract of proposals for excavating rock from the Upper Columbia and Snake Rivers, opened by Major John M. Wilson, Corps of Engineers, November 10, 1876.

Number.	Names and residences of bidders.	Squally Hook Rapid, Upper Columbia River, 100 cubic yards, more or less, per cubic yard.	Pine-Tree Rapid, Snake River, 300 cubic yards, more or less, per cubic yard.	Remarks.
1	Grant & Stone, The Dalles, Oreg	$23 00	$28 00	Contract for Squally Hook awarded.
2	J. B. Montgomery, Portland, Oreg	27 50	24 75	Contract for Pine Tree awarded.
3	Thomas J. Stump, Wallula, Wash. Ter	....	28 50	No bid for Squally Hook received.

Proposals for this work were invited by letter, without advertising, owing to the lateness of the season, as per letter of authority from the Chief of Engineers, dated September 15, 1876.

Abstract of contracts for the improvement of the Upper Columbia and Snake Rivers, in force during the fiscal year ending June 30, 1877.

Number.	Names and residences of contractors.	Date of contract.	Subject of contract.	At Upper Umatilla Rapids, Columbia River, 200 cubic yards, more or less, per cubic yard.	At Pine Tree Rapids, Snake River, 400 cubic yards, more or less, per cubic yard.	At Squally Hook Rapids, Upper Columbia River, 100 cubic yards, more or less, per cubic yard.
1	J. B. Montgomery, Portland, Oreg.	Sept. 2, 1876	Excavating rock	$31 00	....	....
2	J. B. Montgomery, Portland, Oreg.	Nov. 11, 1876	......do	....	$24 75	....
3	Grant & Stone, The Dalles, Oreg.	Nov. 20, 1876	......do	....	....	$23 00

JJ 4.

CONSTRUCTION OF A CANAL AROUND THE CASCADES OF THE COLUMBIA RIVER, OREGON.

By the act of Congress approved August 14, 1876, an appropriation of $90,000 was made for the construction of a canal around the Cascades of the Columbia River, in the State of Oregon, and by telegram of October 24, 1876, I was instructed to "proceed at once with survey, plan, location, and project of construction."

A preliminary reconnaissance was made in November, and early in December a party was placed in the field, in charge of Assistant Engineer C. M. Bolton, with instructions to make a careful and elaborate survey of the country on the Oregon side of the rapids—*upon which side the law required the canal to be constructed*—an accurate and rapid reconnaissance of the Washington Territory side, a hydrographic survey of the river above and below the rapids, with current-observations, &c., wherever the work could be done without danger to life, and a close examination

of the underlying material upon the line which should be finally selected for the canal.

These instructions were carried out with great energy and skill by Mr. Bolton, who, in spite of the inclement season, kept his party at work steadily, and by the early part of January the field-work was completed, the party disbanded, and the work of preparing charts, plans, and estimates at once commenced.

On February 5, 1877, I submitted a preliminary report, which was laid before Congress on February 26; and on April 12 I forwarded a full report, with estimates, and a chart showing the proposed location of the canal.

PROPOSED ROUTE OF CANAL.

As the law plainly states that the canal shall be in the State of Oregon, the line was at once settled within certain limits by its terms, as the principal conditions would require that it should be upon the shortest available route, have the least number of locks possible, and be fed entirely from the Columbia River.

The route selected, as stated in my report of April 12, commences on the Oregon side, just above the main rapid, runs through a plateau covered with heavy bowlders, mingled with sand and gravel, resting upon bed-rock, and closely hugging the Oregon shore, is continued after the fall is made in the river proper by a crib-work breakwater about 5,000 feet long.

DIMENSIONS OF PROPOSED CANAL.

The dimensions of the proposed canal will be as follows:

	Feet.
Total length, including crib-work breakwater	7,200
Width in cutting at surface at low-water	58
Width in cutting at bottom at low-water	50
Depth at low-water	8

The fall at low-water, 26 feet, will be overcome by two locks; these locks will be 250 feet long, 46 feet wide, with a depth of 8 feet on the miter sill at dead low-water; the lifts will be 12 and 14 feet; there will be a guard-gate at the upper end of the canal, to be closed when repairs are necessary or large quantities of drift running, or for a few days in case extreme high-water equal to that of 1876 should again occur.

Estimates have been presented for a canal navigable at all stages when the river is not closed by ice, and for one navigable when the river is not higher than 25 feet above low-water; in the last nineteen years there have been only two summers—those of 1868 and 1869—when the freshet was not higher than 25 feet above ordinary low-water.

The estimated cost of the high-water canal, as previously submitted, is \$1,544,545; that of the canal navigable only when the water is not higher than 25 feet above ordinary low-water is \$1,188,680.

SURVEY FOR CANAL ON WASHINGTON TERRITORY SIDE.

By telegraphic instructions from the Chief of Engineers, dated May 18, 1877, confirmed by letter, I was informed that while the act of Congress approved August 14, 1876, upon which my project of April 12, 1877, was based, confined the canal to the Oregon side, still the act of June 23, 1874, required an examination of both sides of the river, and that "before undertaking an improvement of such magnitude a thorough examination of the locality should be made, so as to be possessed of all data bearing upon its most advantageous location."

An allotment of $1,200 was made for a survey on the Washington Territory side, and I was instructed to present a project in detail, with estimates, for a canal on that side at the earliest practical moment.

The telegram reached me on Saturday, May 19, and on Monday, May 21, a careful preliminary reconnaissance on the Washington Territory side was commenced.

As the Columbia River was rising rapidly, being 23 feet above low-water at the Lower Cascades, the object of this reconnaissance was to determine the most available route to be surveyed for a canal as soon as the freshet should subside.

The creek emptying into the Columbia River near the upper steamboat-landing, just above the falls, which was the only apparent available route in this vicinity, was found to have but little rise for the first half mile, but then divided into three smaller streams, which rose to lakes about a mile farther, at heights from 225 to 300 feet, the ridge which it would be necessary to cross being about the same height; a canal by this route was, therefore, deemed impracticable, except at a great expense, necessitating a high summit-level to be fed from the lakes.

The high water prevented an examination of the lower portion of the slope bordering immediately upon the river; but the tendency to slide of the material of which it is composed would render it a dangerous experiment to cut a canal near the base.

From this reconnaissance it was thought that the best plan for a canal on the Washington Territory side would be to build a dam at the narrow part of the river, about 6,000 feet below the head of the main rapid, and to cut a canal about 800 feet long through the land extending out into the river on the Washington side near this locality.

As a plan and estimate for such a work would necessitate a careful and elaborate survey of the river with soundings on the proposed line of the dam, no work could be done on account of the freshet and the consequent increased velocity of the current.

On June 9 telegraphic instructions were received from the Chief of Engineers, directing the suspension of the survey on the Washington Territory side for the present.

During the season of 1877–1878 it is proposed to continue the preparation of detailed plans of locks, gates, crib-work, &c., and to take such action in reference to commencing construction as may be ordered by the Chief of Engineers.

In the survey and the preparation of the plans and estimates for this work, I have been greatly indebted for earnest, able, and energetic assistance to Assistant Engineer C. M. Bolton, who has displayed zeal and ability in the discharge of the duties assigned to him.

The following statistics required by the act of Congress approved June 23, 1866, are respectfully submitted:

Up to this time $90,000 has been appropriated for this work, being the amount named in the act of August 14, 1876; of this sum $4,616.65 has been expended to date in surveys and preparation of charts, plans, estimates, &c.

The estimated cost of the project submitted is $1,544,545; of this amount $500,000 can be profitably expended during the next fiscal year.

The Cascades of the Columbia River are situated in the collection-district of the Willamette. The nearest port of entry is at Portland, Oreg., 65 miles distant; the nearest light-houses and fortifications are at the mouth of the Columbia River, about 160 miles distant.

I am informed that the number of passengers and the amount of freight passed over the portage railroad at the Cascades by the Oregon Steam

Navigation Company during the first eleven months of this fiscal year are largely in excess of the number and amount transported during the same period in the last fiscal year.

The amount of revenue collected at the port of Portland, Oreg., from July 1, 1876, to June 1, 1877, was $125,317; the value of the imports was $388,476, and of the exports $2,509,159; 177 vessels, with an aggregate tonnage of 152,961 tons, entered, and 153, with an aggregate tonnage of 144,296 tons, cleared. At the port of Astoria, Oreg., during the same period as above, the revenue collected was $26,378, the value of the imports $24,315, and of the exports $1,488,929; the number of vessels entering was 180, with an aggregate tonnage of 200,186 tons; the number of vessels clearing was 194, with an aggregate tonnage of 212,564 tons.

By the construction of the Cascade canal, direct navigation of the Columbia will be opened to the Dalles, a distance of 50 miles beyond the Cascades; the amount of commerce to be benefited cannot be given in figures, but its great increase is anticipated from the fact that the very extensive wheat-growing region east of the Cascades is being rapidly settled.

Charts showing the line of the proposed canal and the river in the vicinity, and also a statement of funds, are transmitted herewith.

Money statement.

Amount appropriated by act approved August 14, 1876	$90,000 00
July 1, 1877, amount expended during fiscal year	4,616 65
July 1, 1877, amount available	85,383 35
Amount (estimated) required for completion of existing project	1,459,136 40
Amount that can be profitably expended in fiscal year ending June 30, 1879	500 000 00

J J 5.

EXAMINATIONS WITH A VIEW TO ESTABLISHING A HARBOR OF REFUGE ON THE PACIFIC COAST.

REPORT OF THE BOARD OF ENGINEERS FOR THE PACIFIC COAST.

OFFICE BOARD OF ENGINEERS FOR THE PACIFIC COAST,
San Francisco, Cal., February 14, 1877.

GENERAL: In compliance with the instructions of the Department of May 9, 1876, enclosing a resolution of the House of Representatives of April 29, 1876, "asking for an examination of the harbors of Mendocino, Humboldt Bay, Trinidad, and Crescent City, in the State of California, with a view of establishing a breakwater and harbor of refuge, with estimate of probable cost," the Board of Engineers for the Pacific coast has the honor to submit the following

REPORT.

The Board sailed from this city on the 9th of August last in the Coast Survey steamer Hassler, and carefully examined all the so-called harbors where it has been thought a harbor of refuge might be constructed, between here and the mouth of the Columbia River, viz: Drake's Bay,

Mendocino City, Shelter Cove, Humboldt Bay, Trinidad Harbor, Crescent City, Mack's Arch, Port Orford, and Cape Gregory.

The Board extended its examinations to all these places because it was by no means clear beforehand that either of the four places mentioned in the resolution of the House of Representatives furnished the best location for a breakwater and harbor of refuge. It is well, also, in such an examination, to have the data necessary to compare the advantages and cost of all the possible locations for such a harbor of refuge on the entire northern coast of California and Oregon.

The distance from San Francisco to Nee-ah Bay, at the entrance of the straits of Fuca, is about 700 nautical miles. While there are many open anchorages scattered along the coast, between these two places, which afford reasonably good protection for vessels against the prevailing northwest winds and seas of summer, there are none, for this entire distance, that a vessel can enter in heavy southerly weather, when the wind is south, southeast, or southwest, as it frequently is in the winter season.

It is true that vessels can generally cross the bar of the Columbia River and seek shelter at secure anchorages in the river, but this is not always the case.

In heavy southerly weather, when a harbor of refuge is most wanted, vessels dare not approach the bar of this river. It cannot, therefore, be considered a secure harbor of refuge.

A good harbor of refuge ought, of course, to provide secure anchorage for vessels against all winds, from whatever direction; but what is more particularly needed on this coast is protection against heavy southerly storms.

One of the first questions which arises in the consideration of this subject is whether, in case protection for vessels is to be sought by artificial constructions, we should build one large breakwater inclosing a capacious harbor, or several smaller ones, distributed along the coast, each affording protection for a few vessels only.

Our examinations and studies of this question have satisfied us that, if any breakwater is to be built on the coast now under consideration, it should be large enough to afford all the protection that is needed for a harbor at that place for the present time and for many years to come.

We are led to this conclusion principally because any construction, at any place on the coast affording secure anchorage for even a few vessels, will necessarily be very expensive, and before undertaking any second work we should profit by the experience to be acquired by the first.

We enclose herewith Coast Survey charts of Drake's Bay, Bodega Bay, Mendocino Bay, Trinidad Harbor, Crescent City, Mack's Arch, Port Orford, and Cape Gregory, on which we have marked in red lines the proper position, in our judgment, of a breakwater for each bay or harbor.

We did not extend our examinations north of the Columbia River, because a harbor of refuge is first wanted south of that river.

We also inclose a section of a breakwater, such as we would propose, which is common to all the above-named places, varying only with the depth of water.

Stone is to be found in great abundance, and very convenient, at all of these places, except at Cape Gregory, where it would have to be obtained some miles to the southward.

The rock on the coast is metamorphic sandstone, and would generally be broken into small pieces in quarrying. Nevertheless, judging from

the solid masses of stone which erosion has left along the sea shores of this coast, we think, in quarrying so large a mass as would be required for the construction of a breakwater, that many large stones of a compact nature could be obtained at almost any quarry that might be opened.

We propose to build the base of any breakwater, up to the height of 15 feet below the level of low-water, of small stone, that is to say, of such stone as any quarry will furnish; and, while quarrying out this great mass, to lay away all large stones of 5, 10, or 20 tons for the construction of that portion of the breakwater from 15 feet up to low-water.

Upon this foundation we propose to build a masonry wall, faced with granite, 25 feet wide and 20 feet high including the foundation, protecting the seaward side by blocks of artificial stone (if natural stone cannot be obtained) of large size, (20 to 30 tons each,) and thoroughly paving the harbor side with large blocks of granite, to receive, without displacement, the water that will be thrown over the wall in great storms.

There is also enclosed a paper in which approximate estimates of costs of breakwaters at the several harbors above mentioned, on the lines as stated, are given.

The Board proceeds to make some remarks about these harbors.

DRAKE'S BAY.

This bay affords fine shelter against west and northwest winds, being sheltered by the high headland of Point Reyes, but it is exposed to south and southwest storms.

Here it may be remarked that throughout the sea-coast of California and Oregon, when the wind is strong from the south, southeast, or southwest, the waves always approach the shore from the southwest; and it is natural that this should be the case; for if we suppose waves to be generated by a southerly wind, having their crests on an east or west line, or even in a direction at right angles to the trend of the shore, the western ends of these waves will be in deeper water than the eastern ends, and, according to the laws of wave-motion, their western ends would travel faster, and thus the crests of such waves would gradually be brought to a northwest and southeast direction, the translation of such wave-motion being from southwest toward northeast.

Any breakwater, therefore, at any of the harbors now under consideration must be so located as to afford protection from the sea in that direction.

There is some granite at Point Reyes, but, as far as examined, it is overlaid with great masses of metamorphic sandstone. Stone for the substructure of a breakwater is in great abundance and very convenient.

We have no idea that a breakwater will be commenced here at the present time. In the distant future, when the commerce of this coast shall be greatly developed, it may be thought necessary to have a sheltered anchorage against heavy gales from the southward, near to the entrance of San Francisco Bay, where vessels bound to this city could seek protection at such times as it was not safe to cross the bar.

BODEGA BAY.

A breakwater here, as indicated on the chart, would protect a fine capacious anchorage, but being some 20 miles farther from San Francisco, and more frequently visited by fogs than Drake's Bay, we are of opinion that, if a harbor of refuge is ever wanted in this vicinity, Drake's Bay should receive the preference.

MENDOCINO BAY.

This is the first place mentioned in the resolution of the House of Representatives upon which we are now reporting. It is only a contracted indentation of the coast, 1 mile wide and less than half a mile in depth, entirely exposed even to the prevailing northwest winds of summer. Nevertheless, a sheltered harbor of refuge, but of very limited capacity, could be made here by building a breakwater on the lines indicated on the chart.

Stone for the foundation of such breakwater can be had in abundance on the adjacent shores.

HUMBOLDT BAY.

This is the second place mentioned in the resolution of the House of Representatives.

This bay affords fine shelter after vessels have once got into it, but it is a bar-harbor the bar being composed of shifting sands, with heavy breakers even in moderate summer weather.

To give an idea of the great height of the waves rolling over this bar, we will state that when the Board of Engineers for the Pacific Coast arrived off the bar, in the Coast-Survey steamer Hassler, the weather was very moderate, with only the usual summer wind from the northwest, yet, although there was 20 feet of water on the bar at the time, the pilot refused to take in the Hassler, drawing only 12 feet of water at the time, stating that he could not do so without running the risk of the vessel striking the bottom and her possible loss in the breakers.

The shores on both sides of the entrance are low and sandy, and there is no stone in the immediate vicinity.

The only way, as it appears to the Board, in which a safe entrance could be obtained into this harbor would be by the construction of two parallel jetties of very heavy stone, about 500 yards apart, from the north and south spits at the entrance.

If such jetties were built, the very large area of the inner bay would probably afford sufficient tidal prism to keep open a deep channel over the bar, against all drift from the action of sea-waves. But such construction would be attended with immense difficulties and enormous expense. It is a question even with the members of this Board whether such construction would be physically possible, and one, too, upon which we dare not express an opinion without a searching examination of all the contingencies upon which the stability or instability of such works would hinge. We have not, therefore, made any plan or estimate of cost for a breakwater at this place, deeming it, if not impossible of execution, highly improbable that a breakwater or jetties will be attempted here at the present time.

TRINIDAD HARBOR.

This harbor is in latitude 41° 03′, about 240 nautical miles north-northwest of San Francisco. It is about 20 miles south of the middle point of the coast between the entrance into San Francisco Harbor and the mouth of the Columbia River. Geographically it is, therefore, well situated for a harbor of refuge between these two places.

Trinidad Head, a bold, picturesque headland, protects a limited anchorage from northwest winds, but the harbor is entirely exposed to southerly storms. This headland rises to the height of 380 feet above low-water. It is of metamorphic sandstone, covered, above the height of

80 to 100 feet above the water, with a few feet of earth which supports a thick growth of scrub bushes.

The rock here appears to be of better quality than is generally found along the coast. The fact that it is such a bold, projecting headland, with deep water around its southern face, shows that it has been able to resist the denudation of the sea, and would seem to bear out this conclusion.

The chart shows the lines we have selected for the breakwater. If built as we have indicated, they would protect an available anchorage of nearly one square mile, with good holding ground.

If a harbor of refuge is made here, the light-house now on Trinidad Head should be removed to Pilot Rock.

There would be several rocks in the northern part of a harbor here, but they rise high above water.

There are no sunken dangers in approaching Trinidad, for the only rocks to be found lie close inshore, just off the high headland, and their position is well marked by two high rocks, one of which rises to the height of 80 feet, the other to the height of 100 feet, above the water.

The Board was favorably impressed with the advantages of Trinidad for a harbor of refuge; and as it is called upon to "designate the point which should, in its judgment, be selected for such harbor between San Francisco and Puget's Sound," the Board, with the information now before it, gives the preference to Trinidad Harbor.

CRESCENT CITY.

This harbor is not favorably situated for a breakwater, because—

1. It is contracted.
2. On account of the many dangers, sunken and otherwise, both in approaching the coast and inside the anchorage.
3. Because of the heavy breakers, in southeast and southwest winds, clear across the entrance to the harbor from Steamboat Rock to Round Rock, from Round Rock to Mussel Rock, and from Mussel Rock to the shore.

The entire harbor is feather-white with breakers in a gale of wind from the southward.

Crescent City Harbor is usually regarded as the most dangerous roadstead on this coast. It has acquired importance on account of the town of Crescent City being conveniently located as the depot of supplies for Jacksonville, in Oregon, and the interior towns and mining-camps. It also has considerable trade in lumber.

A vessel off this coast, and wishing to make a harbor of refuge, would never venture into Crescent City Harbor unless the master knew his position accurately, and was well acquainted with the coast and all the sunken dangers; and should he arrive off the harbor, he could not enter it with safety in heavy southerly weather on account of the breakers at the entrance.

Nevertheless, in order to have definite ideas as to the location and cost of a breakwater here, we have included it among the roadsteads for which we have given plans and estimates for breakwaters.

MACK'S ARCH.

The recent coast-surveys on this coast have developed this roadstead.

It is in Oregon, a few miles north of latitude 42°, which is the northern boundary of California. The anchorage is somewhat protected from

westerly and southwesterly seas by a ledge of high detached rocks extending from the shore toward the big arched rock, which gives name to the location.

A breakwater here would consist in connecting these separate rocks, or little islets, by a construction such as we have proposed, leaving an entrance on both sides of Mack's Arch. Several of these detached rocks are so high that their tops might be quarried off and the stone made to fall into position for the foundation of the breakwater.

Stone is abundant on the adjacent shores. It is of the usual metamorphic sandstone.

The harbor here would be small, but large enough for all present wants and those of the near future. It would be tolerably secure, and the holding-ground is good.

There are no settlements in the immediate vicinity.

PORT ORFORD.

This place is the best summer roadstead on the entire coast between Point Reyes and the Straits of Fuca. When vessels anchor close in to the northern shore they are protected, by a high point of land and some outlying islets to the south of it, from the summer waves coming from the west or northwest. The harbor, however, is entirely exposed to the southerly gales of winter, when the great rollers approach the shore from a southwest direction.

This port is well located for a harbor of refuge.

Stone for the foundation of a breakwater is abundant in the immediate vicinity.

The holding-ground is good, and, doubtless, it would be possible to make a good harbor of refuge here by the construction of a breakwater, about 1 mile long, on the line we have indicated.

Our only objection to it is the great depth of water on the proper line of breakwater, and consequent enormous cost.

There is the further objection to making a breakwater here that about half-way between Port Orford and Cape Orford, and some 3 miles off the coast, there is to be found a great group of rocky islets and sunken rocks, called Orford Reef, which render the approach to Port Orford from the north somewhat dangerous.

CAPE GREGORY.

This is the only place on the coast, between San Francisco Bay and Nee-ah Bay, that affords protection for vessels in a southerly or southeast gale.

The anchorage is protected from heavy seas from the southwest by a tongue of land some 20 or 30 feet wide on top and 50 to 60 feet high, extending out to, and a short distance beyond, the light-house, but it is entirely exposed to the north and northwest seas. From there, for a quarter of a mile farther, protection is given by a rocky ledge extending out to sea in a north-northwest direction.

This tongue of land, upon which the light-house is situated, is an island connected with the main-land by a wooden bridge. The tongue is rock, overlaid with earth, which supports a luxurious growth of grasses, with some pine trees.

The Coast-Survey chart of this bay not being as yet completed, we took more than 100 soundings in and around the bight northeast of Cape Gregory.

A few characteristic ones are noted on the chart herewith, all reduced to the plane of low-water.

Deep water is found close inshore.

Rock is not abundant here in the immediate neighborhood, but, doubtless, plenty could be found in a distance of a few miles from the light-house.

The character of the formation close to shore appears to change at the entrance to Koos Bay. To the south it is high and rocky; toward the north it is low and sandy.

A breakwater half a mile long, as indicated on the chart, from the end of the rocky ledge, and at right angles to it, would furnish a safe harbor about half a mile square.

The places named in the foregoing review are the only open-sea harbors between San Francisco and the Straits of Fuca, so far as we are informed, where it would be possible to make a harbor of refuge.

Humboldt Bay and Koos Bay, south of the Columbia River, and also Shoalwater Bay and Gray's Harbor, north of that river, are all good land-locked harbors; their entrances being obstructed by bars of sand, over which the sea breaks almost incessantly, and often with great violence.

We think the only way a safe entrance into these inclosed harbors could be obtained would be by the construction of two parallel dikes, or jetties of heavy stone, extending from deep water in the harbors out to deep water in the ocean.

The tidal prism in all of these inland harbors is very large, and if such jetties could be built they would make safer harbors of refuge than would be attainable in an open roadstead.

Doubtless such jetties could be built but without any experience in such constructions, either in this or foreign countries, the Board has refrained from making any plans or estimates for the four land-locked harbors above named.

NECESSITY OF A HARBOR OF REFUGE BETWEEN SAN FRANCISCO AND PUGET SOUND.

We have deferred the consideration of this subject to the close of this report, because to judge of the necessity of a harbor of refuge we ought to know, approximately at least, the cost of such harbor and the value of the shipping which would seek protection in it.

If the cost of such a harbor is out of all proportion to the value of the property seeking its protection, or, strictly speaking, if the annual interest on the cost and maintenance of such a harbor is greater than the value of the vessels and cargoes that might be lost or damaged for the want of it, political economy would say that it ought not to be built.

We are aware that other considerations ought to enter as factors in the decision of this subject, such as the value of the lives that may be lost for the want of a harbor, and the constant apprehension of danger on such a long line of exposed coast, and consequent enhanced insurance.

Again, the commerce of this coast is increasing rapidly, and although the time may not yet have arrived when the Government would be justified in constructing an expensive harbor, yet, if this commerce goes on increasing as rapidly in the future as it has in the past, that time will arrive at no distant day.

Here, again, it is difficult to draw a line of demarkation between the

present and the future; for the construction of any of the breakwaters we have named will necessarily occupy many years. If we fix upon any future time when a harbor of refuge will be demanded in the interests of commerce, then the construction of that harbor should be commenced many years before that time.

To illustrate these ideas practically we will refer again to Trinidad Harbor, which is the one to which we give preference.

We will suppose that it is decided to build a harbor of refuge at this place, and in the first instance to construct only the portion represented by the lines *a*, *b*. *b*. *b*[1]; the two distances being 2,200 feet.

Now, in this portion of the work there is, as we have planned it, 762,000 cubic yards of stone, or disregarding the void spaces between the stone, which would be about a proper allowance for the stone that might be washed away by storms during the construction, and allowing 2 tons to the cubic yard, we have 1,524,000 tons of stone.

If we suppose the sea to be sufficiently smooth to permit work to be prosecuted, on an average, for 200 days in the year, and that we can quarry, transport, and put in place 1,000 tons of stone for each of these 200 days, the construction of this portion of the breakwater would occupy 7.6 years.

We are aware that the portion of the breakwater we are now considing, having one end connected with Trinidad Head at a central position, with quarries to the right and left, and one-half mile long if necessary, affords great facilities for rapid construction.

If sufficient funds were appropriated, so that work would not have to be suspended for want of money, it is probable, with the aid of proper appliances, such as steam-cars, steam-drills, steam-derricks, and an elevated superstructure along the line of the breakwater, it might be possible to quarry and put in place as much as 5,000 tons of stone per day, in the substructure and heart of the work, up as high as the level of 15 feet.

At this rate, this portion of the construction would only occupy 218 working days, after the quarries were once opened and all the auxiliary arrangements completed.

Although this substructure contains the greatest mass of stone in the work, its construction would not necessarily occupy the greatest time. The heavy stone above, between 15 feet and low-water, could not be handled so rapidly. Nor could the protecting mass of outside stone, or the paving on the harbor side.

But it is the construction of the wall of cut-stone masonry which would occupy the most time. Its foundation would be tide-work, requiring a combination of favorable circumstances to enable it to be placed—such as low tide and a smooth sea. In fact, the construction of the entire wall would, to a more or less extent, require these favorable conditions.

For these reasons we think that 1,000 tons is a fair estimate of the quantity of stone that could be placed in position, for each working day, as applied to the entire mass of stone in the breakwater.

To construct the entire breakwater on the lines *a*, *b*, *b* *b*[1], *c*, *d*, and *d*, *e*, at the rate we have supposed, would occupy 17.9 years.

If, therefore, we can fix upon any time in the future when the wants of commerce will require a breakwater here, or, in fact, at any other point on the coast now under consideration, it is manifest from the great magnitude of the work, as well as the uncertainty of the appropriations, that such a construction should be commenced some twenty years before that time.

To enable us to arrive at some conclusion in regard to this period, we

have compiled from the records of the custom-house in San Francisco, the following statement showing the import and export trade of merchandise, by sea, from this city, and the tonnage and number of vessels arriving and departing for several years:

	1874.	1875.	1876.
Value of imports	$31,529,708	$35,708,782	$37,559,018
Value of exports	28,425,248	30,554,081	31,314,782
Total	59,954,956	66,262,863	68,873,800

	1876.	
	Number.	Tonnage.
Vessels arrived from foreign ports	631	723,379
Vessels cleared for foreign ports	659	760,770
Total	1,290	1,484,149

Total arrivals during the years—

	1874.	1875.	1876.
Number of vessels	4,204	4,350	4,635
Tonnage	1,548,841	1,584,123	1,793,091

Assuming that the number and tonnage of vessels departing is the same as that for arriving, we would have a grand total for the year 1876, of—

Number of vessels arrived and departed	9,270
Tonnage of vessels arrived and departed	3,586,182

Much of this commerce would not receive any benefit from a harbor of refuge located at any point between San Francisco and the Columbia River.

All outward-bound vessels from San Francisco to more southern ports, or around Cape Horn, do not require a harbor of refuge north of this city; but on their return-trips the case is somewhat different, for sailing-vessels bound to San Francisco from any southern port usually stand well off-shore, and hold their course to the northward until they have passed the latitude of San Francisco. The prevailing northwest winds then enable them to approach the coast in the vicinity of Point Reyes, or at least north of this city, and have a fair wind for entering the harbor.

It is, however, the commerce passing along or near the northern coast of California and the coast of Oregon which is more directly interested in a harbor of refuge on the portion of the coast we are now considering. We have been unable to ascertain the amount of this commerce or the number of vessels engaged in it.

Both Trinidad Harbor and Port Orford are well situated, geographically, for a harbor of refuge for all vessels bound from San Francisco, or any southern port, to all northern Pacific-coast ports of the United States or British Columbia, and Trinidad Harbor is only 130 nautical

miles from the arc of a great circle between San Francisco and Yokohama or Hong-Kong.

Sailing-vessels to or from San Francisco for Japan or China usually take the northern passage, or the arc of a great circle between their points of departure and destination. The steamers, however, take a more southerly route.

Respectfully submitted.

G. H. MENDELL,
Major of Engineers.
R. S. WILLIAMSON,
Lt. Col., U. S. Engineers.
B. S. ALEXANDER,
Lt. Col. of Engineers, Prest. Board of Engineers, Pacific Coast.

I concur in general with the views expressed in above report, but differ from the majority in regard to cross-section and plan submitted.

C. SEAFORTH STEWART,
Lt. Col. of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

ESTIMATES OF COST (GOLD COIN) OF BREAKWATERS AS PROPOSED FOR VARIOUS HARBORS OF REFUGE ON THE PACIFIC COAST BETWEEN SAN FRANCISCO AND THE COLUMBIA RIVER.

Drake's Bay.

For one mile long	$6,168,909
Add 10 per cent. for contingences	616,891
Total	6,785,800

Bodega Bay.

For section *a b*	$580,000
For section *c d*	448,000
For section *e f*	1,130,000
For section *f g*	3,855,000
	6,013,000
Add 10 per cent. for contingences	601,300
Total	6,614,300

Mendicino Bay.

For section *a b*	$1,231,250
For section *c d*	1,909,750
	3,141,000
Add 10 per cent. for contingencies	314,100
Total	3,455,100

Trinidad Harbor.

For section *a b*	$2,788,500
For section *b b*[1]	288,000
For section *c d*	2,009,000
For section *e f*	1,909,500
	6,995,000
Add 10 per cent. for contingencies	699,500
Total	7,694,500

Crescent City.

For section *a b*	$1,771,700
For section *c d*	3,703,700
	5,475,400
Add 10 per cent. for contingencies	547,540
Total	6,022,940

Mack's Arch.

For section *a b*	$597,400
For section *c d*	704,950
For section *e f*	557,700
For section *g h*	1,174,200
For section *i k*	2,192,000
	5,226,250
Add 10 per cent. for contingencies	522,625
Total	5,748,875

Port Orford.

For section *a b*	$4,538,720
For section *b c*	4,524,260
For section *d e*	489,150
	9,552,130
Add 10 per cent. for contingencies	955,213
Total	10,507,343

Cape Gregory.

For one-half mile	$3,372,880
Add 10 per cent. for contingencies	337,288
Total	3,710,168

APPENDIX K K.

IMPROVEMENT AND CARE OF THE PUBLIC BUILDINGS AND GROUNDS IN THE DISTRICT OF COLUMBIA, AND THE WASHINGTON AQUEDUCT.—REPORTS FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

K K 1.

REPORT OF COLONEL O. E. BABCOCK, CORPS OF ENGINEERS, FOR PART OF THE FISCAL YEAR ENDING JUNE 30, 1877.

GENERAL: I have the honor to submit the following report of the operations on the works under my charge from July 1, 1876, to March 3, 1877, at which time I was relieved from the duties of the office. (Special Orders No. 44, Headquarters of the Army, A. G. O., Washington, D. C., February 27, 1877.)

As no appropriation bills for the service of this office were passed until August 14, but little work was done from the commencement of the fiscal year until after that date. The work done consisted in watering and mulching a large number of trees—evergreens and others—which were planted in the spring, and were suffering on account of the unusually hot and dry weather of July. The young trees in the nursery were also cared for at the same time and in the same manner. The employment of the force to do this work was under the acts of Congress making appropriations for the temporary expenses of the Government, approved June 30, 1876.

I regret to state that during this heated spell one of the laborers on the regular force (an old soldier) died from the effects of a sun-stroke. Having left no means from which the necessary funeral expenses could be paid, the expenses were paid by the employés of the office.

The watchmen in Lincoln, Judiciary, and Rawlins Squares, Washington Circle, and Pacific Place, and two in the Smithsonian grounds were discharged August 14, 1876, Congress having made no appropriation for their payment after that date.

M'PHERSON (FORMERLY SCOTT) SQUARE.

After the completion of the pedestal for the equestrian statue of Gen. James B. McPherson, and the placing of the statue on the same, the square was cleaned and put in proper condition. During the improvement of this square it became necessary to remove a number of trees and shrubs. Those of value were transplanted to the nursery for future use.

Four large bronzed vases were purchased and placed in position around the statue. To protect them from action of frost they were placed on brick foundations.

The work of erecting the pedestal and of placing the statue thereon was performed without accident of any kind. These improvements add much to the beauty of the square.

This statue was unveiled on October 18, 1876, with appropriate ceremonies, in which the President and Cabinet, members of the Supreme Bench, officers of the Army and Navy, and citizens of Washington in general participated. At the request of intimate friends, approved by the mother of General McPherson, an attempt was made to bring his remains to Washington and place them within the foundation of the pedestal. When partially disinterred, an injunction was issued by the State court of Ohio, at the solicitation of the representatives of the Clyde (Ohio) Monumental Society, and all further attempts to remove them were abandoned.

LINCOLN SQUARE.

At the request of Mr. J. E. Yeatman, of Saint Louis, the president of the Western Sanitary Commission, having charge of the funds subscribed by the colored people of the United States for procuring and presenting to the Government the Lincoln Group, this office designed, procured, and placed in position the two bronze inscription-plates now on the pedestal. The entire cost of procuring and placing these plates in position was defrayed by said commission.

These plates are ornamental, and give a brief history of the manner in which the "Group" was obtained and presented to the Government.

The trees, walks, &c., in the square were properly cared for during the season, and all are in good condition. The grass was cut several times during the year without cost to the office, the parties cutting the same, under charge of the watchman, taking the grass for their pay.

GROUNDS SOUTH OF THE EXECUTIVE MANSION.

A large quantity of earth was deposited in these grounds during the year, and was used in grading them, the necessary force being employed for that purpose.

The greater portion of the earth received was from Pennsylvania avenue, removed in grading for the new pavement authorized by Congress. Nothing was paid the contractors for this earth, and but little was paid for earth deposited by others, owing to the limited appropriations made for these grounds. As the filling of the grounds progressed, it became necessary, in the lower portions, to provide for carrying off the water that collected there after rains, and which would soon form pools of stagnant water injurious to the public health. This was done from time to time by constructing wooden drains and connecting them with the sewers along B street north. While not of a permanent character, they answer the purpose admirably. The improvement contemplates tile-draining these grounds, when the temporary drains will no longer be required.

A large quantity of the sweepings from the streets of the city was dumped in these grounds and placed in piles, and being of more value than the earth ordinarily deposited, is reserved for soiling when the final grade is completed. As good soil for final grade is difficult and quite expensive to procure, these sweepings will be of much value in preparing the grounds for seeding and planting. No payment was made for these sweepings.

The roadways were repaired from time to time as was necessary; the gutters were kept free from weeds and in good repair, and the walks were occasionally swept and cleaned.

The small space which incloses the building south of the Treasury Department was graded, soiled, and sown with blue-grass seed, an improvement much needed.

MONUMENT GROUNDS.

A portion of these grounds north of the monument was graded, soiled, and sown with rye and blue-grass seed, completing the grading of these grounds, with the exception of a small portion occupied by the buildings of the Washington Monument Association—one occupied by monument-keeper, the other containing memorial stones for the monument. To protect the slopes of the ground thus graded and to carry the water from them to the lake without injury to its banks, two lodges were constructed at the bottom of the slopes and 125 feet of sewer-pipe were laid to conduct the water to the bottom of the lake.

The island in the western lake was covered with good soil, sown with rye and blue-grass seed, and a number of trees, shrubs, and flowers were planted. Its banks were outlined, graded, soiled, and sodded to the water-line; below that to the bottom of the lake, a depth of 4 feet, the banks were protected from the action of the water by paving with cobble stones, thus giving the banks a permanent and ornamental finish. The west side of the roadway, between the lakes, was in like manner graded, sodded, and paved, thus giving the banks of the lakes, roads, and the island a uniform appearance. The forming of these lakes, the roadway between them, and the extension of Virginia avenue, amounting in all to about fifteen acres, has, without doubt, been very beneficial to the general health of the vicinity. Sheets of pure water, green lawns, and roadway now occupy the space formerly a marsh overgrown with vegetable matter left to decompose and decay, necessarily producing much malaria. During the long, cold period of the winter these lakes afforded fine skating, a favorite resort for ladies and gentlemen as well as children. Every facility was afforded to keep the ice in good condition for skating.

The necessary repairs to the gravel roadways in these grounds were made from time to time, removing such large stones as worked to the surface.

GREENHOUSES AND NURSERY.

The necessary repairs preparatory to winter were made on the greenhouses in the nursery. The plants passed through the unusually cold winter in good condition. The appropriation being small, a less force than usual was employed in the greenhouses caring for the plants and propagating new ones for bedding out in the public grounds and for the usual spring distribution to members of Congress and others.

The thousands of small trees in the nursery have been carefully cultivated, and have made a fine growth, and promise to be valuable for future planting. A quantity of choice tree-seed was gathered, properly cured, and packed for planting at the proper time. For the protection of the foundations of the greenhouses from the effect of surface-water a cobble-stone gutter was constructed around them and connected with the underground drains.

LAFAYETTE SQUARE.

The walks in this square were kept free from weeds and were repaired when required. The grass was cut frequently and the trees were trimmed at the proper season.

The gun-carriages supporting the captured cannon that surround the statue of Jackson having become decayed, were, at the request of this office, kindly removed and new ones substituted by the Chief of Ordnance of the United States Army.

VARIOUS RESERVATIONS.

The roadways in the Smithsonian grounds, Armory Square, and the reservations between Third and Sixth streets and Maryland and Maine avenues, were kept in good repair. Most of them received a coating of screened gravel, 1,334 cubic yards of gravel being used for the purpose. The trees and shrubs in these grounds, as well as those in Lafayette, Franklin, Rawlins, Farragut, and McPherson Squares, the Thirteenth-street, Washington, and Fourteenth-street circles, and the various inclosed triangular reservations throughout the city, were properly cared for. The grass was mowed in them from time to time, as was necessary. The grass that was cut in the Smithsonian and Armory Square grounds was cured, stacked in the nursery grounds, and used in feeding the public animals. The appropriation for various other reservations being very small, but little besides ordinary care could be undertaken.

In Armory Square the banks south of the roadway that enters there from Sixth street were graded, soiled, and sodded, and a cobble-stone gutter laid on each side of the roadway. This work adds much to the appearance of these grounds. It was the intention of the office to improve eastern side of Sixth street in a similar manner as soon as means were available.

TRIANGULAR RESERVATION, PENNSYLVANIA AVENUE AND SEVENTH STREET.

At the request of the property-owners in this vicinity and the gentlemen doing business on D street, opposite to this reservation, I removed the old iron fence that surrounded it and replaced it with the iron post and chain. The improvement was made from the appropriation for repairing iron fences, and at a cost of only $250.

TREES, ETC.

The landscape-gardener was sent in the fall to various nurseries in the North and made purchases of such trees, shrubs, and plants as were desired for planting in the various reservations and the appropriation would warrant. The stock purchased was received in good condition, temporarily placed in the nursery, and during the fall was planted in the various reservations in numbers as follows:

Monument grounds	186
Judiciary Square	93
Farragut Square	24
Rawlins Square	40
Mount Vernon Place	53
Reservation, New York avenue, between Tenth and Twelfth streets	28
Reservation, Massachusetts avenue, between Tenth and Twelfth streets	109
Reservation, Massachusetts avenue and Sixth street	10
Smithsonian grounds	408
Grounds south of Executive Mansion	37
McPherson (Scott) Square	19
Thirteenth-street circle	113
Reservation, New York avenue and Thirteenth street	9
Reservation, Pennsylvania avenue and Eighteenth and Twenty-first streets	60
Reservation, Third street and Missouri avenue	257
Armory Square	662
Reservation on Capitol Hill	226
Reservation, Missouri avenue and Sixth street	113
Franklin Square	5
Total	2,452

The greater portion of the trees planted were mulched, and many of them were firmly secured to the ground with wires and stakes to prevent injury by the wind.

SNOW AND ICE.

The snow and ice were promptly removed from the walks in front of the reservations under charge of this office.

SEATS.

The seats in the public grounds where broken were repaired, and those torn from their fastenings were refastened.

VASES.

The vases intended for plants were filled in the spring with ornamental plants and flowers, which were properly cared for until cold weather required their removal to the greenhouse, when they were replaced by hardy evergreens for winter decoration. There being nineteen of these vases, a large number of plants were required to fill them and considerable attention to keep them in proper condition.

FOUNTAINS.

The various fountains and bowls received such repairs during the year as were necessary to keep them in perfect order. In the fall the water was turned off, the bowls were filled with leaves swept from the lawns, and the copings were thatched with evergreens to protect them from injury by frost.

MANURE.

Manure from the public stable and various private stables was collected and piled in Monument grounds for future use, at the expense of collecting only.

PAINTING FENCES.

The iron fences that inclose Lafayette and Franklin Squares, the Executive Mansion grounds, and the Fourteenth-street circle, together with lamps, lamp-posts, and drinking-fountains connected therewith, received two coats of paint.

LODGES.

The various lodges and urinals in the parks received such repairs as were required.

TELEGRAPH-LINE.

The Department telegraph-line, connecting the Capitol with the Departments, was kept in good working order, but few and quite temporary interruptions occurring to same.

ANIMALS.

The Engineer Department having instructed me that no appropriation for the year could be used in feeding the animals, (deer, eagles, owls, prairie-dogs, and sparrows,) I gave the buck to the gate-keeper at the receiving-reservoir, Washington Aqueduct, and fed the others with food from the reservations and from my personal means.

EXECUTIVE MANSION.

All repairs required were made from time to time, and such refurnishing done as the President's family required and the appropriation afforded. The house and its contents were kept in excellent condition.

During the Centennial Exposition the number of visitors to the Man-

sion was very great, averaging nearly 2,000 daily. The number was so great that it was found necessary for their preservation to take up the carpets on the first floor. They were replaced later in the season.

The greenhouses connected with the Executive Mansion received during the autumn such repairs as were necessary for the proper protection of the valuable stock of plants during the winter.

The grounds in front of the Mansion surrounding the fountains were planted with tropical and semi-tropical plants from the greenhouses, ornamental bedding, and flowering plants, producing a very pleasing effect when viewed from the Mansion or from the avenue. All of the valuable plants thus used made a good growth, and were removed to the greenhouse in time to prevent damage by frost.

WATER-PIPES.

The line of pipe conducting water from Smith's spring to the Capitol was repaired where necessary, and the flow to the Capitol was uninterrupted. A water-gauge was attached to this pipe near the Baltimore and Ohio Railroad depot, for the purpose of locating any leak that may occur, and to save the expense and delay in searching for same.

The house and fence inclosing the spring were repaired and whitewashed.

The pipes in the Smithsonian grounds were extended 2,200 feet, and two drinking-fountains, and globe-valves for irrigating purposes, were placed in position and the water turned on.

The pipes in other reservations were kept in good repair.

BRIDGES.

Chain Bridge was inspected and found to be in good order. No interruption of travel over it occurred during the year. The watchman in charge of this bridge suffers more or less every year from malarial fever, caused to a great extent, in my judgment, by the improper condition of the lodge furnished him. A properly-constructed house should be provided. The Navy-Yard and Benning's Bridges received all necessary repairs, so that travel was uninterrupted during the year.

Financial statement.

The appropriations made for this office for the fiscal year ending June 30, 1877, and the amount expended by the office to the date of transfer, March 3, 1877, are as follows:

Title of appropriation.	Amount appropriated.	Expended to Mar. 3, 1877.	Unexpended.
Repairs, fuel, &c., Executive Mansion, 1877	$17,000 00	$12,880 85	$4,119 15
Improvement and care of public grounds, 1877	30,000 00	23,118 23	6,881 77
Salaries of employés, public buildings and grounds, under Chief Engineer, 1877	32,460 00	21,310 24	11,149 76
Repairs of water-pipes and fire-plugs, 1877	5,000 00	4,388 46	611 54
Contingent expenses, Public Buildings and Grounds, under Chief Engineer, 1877	500 00	449 30	50 70
Repairs of Navy-Yard and Upper Bridges, 1877	1,000 00	284 00	716 00
Lighting, &c., Executive Mansion, 1877	19,000 00	12,918 75	6,081 25
Telegraph to Connect the Capitol with the Departments and Government Printing-Office, 1877	500 00	463 75	36 25
Improvement of Judiciary Square, act of Congress approved January 20, 1877	2,000 00	....	2,000 00
Amounts	107,460 00	75,813 58	31,646 42

It will be seen by this statement that the total sum appropriated is $107,460, and the expenditure $75,813.58, leaving a balance unexpended of $31,646.42; also that the expenditure exceeds two-thirds of the appropriation by $4,174. This excess was caused by the expenditure of certain items of the appropriation, such as coal, cleaning off snow and ice, and the repairs to the greenhouses to protect the plants during the winter months, and similar necessary repairs.

The expenditures for all purposes have been kept within the limits of the appropriations therefor, and no deficiency has been created.

It affords me great pleasure to again bear testimony to the efficient, zealous, and untiring service rendered the Government by my assistant, Mr. George D. Benjamin; Mr. Balloch, the clerk; Mr. George Brown, the landscape-gardener; Mr. W. H. Bailey, in charge of plumbing and gas-fitting, and other employés.

On the Washington Aqueduct, I am indebted to Theo. B. Samo, the assistant engineer; John Ellis, assistant superintendent; and R. Dunning, the clerk, for untiring and faithful service during the entire time.

WASHINGTON AQUEDUCT.

At the date of the last annual report, a contract had been entered into with Messrs. Asa Snyder & Co., of Richmond, Virginia, for building a wrought-iron truss-roof and galvanized-iron cornice on the gate-house at Great Falls.

Messrs. Snyder & Co. commenced work in August, and fully completed their contract in the following February.

Under authority of the resolutions of Congress, extending certain appropriations for the fiscal year ending June 30, 1876, so as to provide for the necessary expenses of the Government for the month of July, the regular employés of the aqueduct were retained during the month, and the work done was limited to the proper supervision of the distribution of Potomac water in the conduit, reservoirs, and pipe-line.

By act of Congress approved July 31, 1876, an appropriation was made for the fiscal year ending June 30, 1877, as follows:

For engineering, maintenance, and repairs	$18,000
For repairs of Georgetown reservoir	4,000

The work done under this appropriation during the year was done by day's work, and the materials used were purchased in open market.

In August, at Great Falls, repairs to the Potomac dam were commenced by replacing the backing of ripraps, which had been carried over the dam by freshets.

At the receiving-reservoir, repairs were commenced to the wooden bridge over the waste channel. A new floor was laid, and the posts of the bents were renewed with sound timber. At the distributing-reservoir, the iron cornices of the gate-houses were painted. Between the receiving and distributing reservoirs, the ditches along the conduit road were cleaned out and the embankments which had been damaged by the rains were repaired.

At Georgetown, the repairs of the high-service reservoir were commenced.

In September, the repairs to the Potomac dam were finished. Between Great Falls and the receiving-reservoir, the embankments which had been washed very much by the rains were repaired, and the repairs to the wooden bridge over the waste channel were completed. At Georgetown, the repairs to the high-service reservoir were continued.

In October, new fences were built around the wells of culverts, slight

repairs after a freshet in the river were made to the Potomac dam, and the repairs to the high-service reservoir were completed.

This reservoir had not been used for the storage of water since the 7th of December, 1875, when, a leak having been discovered therein, it was emptied out. The repairs were commenced immediately after the appropriation therefor had been made by Congress, and they were fully completed on the 6th of October.

The work done consisted in uncovering the forcing-main and recalking its leaky joints. The pipe-trench was refilled with clay-puddle. The cracks in the concrete bottom were cut out and filled with hydraulic-cement mortar; and a layer of concrete, from 9 to 16 inches in thickness, was placed over the entire bottom, a circle of 120 feet in diameter.

On the 7th of October, the reservoir was filled with water to a minimum depth of 16 feet. Since then it has been in constant use and has not leaked.

Concrete was made in the following manner: Two platforms were built, each 12 by 15 feet, of 1½ inch boards. On one platform the sand and cement were mixed dry, then cast on to the other platform in the form of a basin, into which was poured sufficient water to make mortar. This made a batch of mortar about 8 feet by 5 feet by 3 inches thick, on which was spread broken stones. The whole was then turned twice over with shovels, deposited in place, and lighly rammed with wooden rammers. The entire bottom was then plastered to a uniform surface. Each batch of concrete consisted of one barrel of "Roundtop" cement, 2 barrels of sand, 5 barrels of broken stones, and from 8 to 10 buckets full of water, and these materials, when made into concrete, averaged 22½ cubic feet for each batch.

The ornamental iron cornice of this reservoir and the iron fences on Road and High streets were thoroughly painted.

In November, between Great Falls and the distributing-reservoir the macadam road was repaired and the ditches were cleaned out.

At Georgetown, the floor of Rock Creek Bridge was repaired.

In December, a 2-inch iron pipe was laid at the receiving reservoir, connecting a spring with the gatekeeper's dwelling, a forcing-pump was erected, and the dwelling supplied with spring-water.

Near the distributing-reservoir a leak occurred in the 30-inch main. The Potomac water was shut off therefrom, the pipe was banded, and a new joint was cast in front of the bell.

In January, at the receiving-reservoir, a channel for boats was cut through the ice to the sluice-tower and kept open during cold weather; the ice was 18 inches thick. At the distributing-reservoir the stone remaining on hand was broken and used to repair the conduit-road.

In Georgetown, at the high-service reservoir, laborers kept the snow cleaned off the foot-ways of Road and High streets.

From the 20th to the 27th of January, the officers of the Signal-Service Bureau were permitted to use the Washington Aqueduct telegraph for the purpose of reporting the condition of the Potomac at Great Falls and Harper's Ferry during freshets.

In February, the embankment over culvert No. 18, was repaired. Repairs were also made to the macadam road.

The following is a financial statement to March 3, 1877:

TITLES OF APPROPRIATIONS.

Act of March 3, 1875.

For building iron truss-roof on gate-house at Great Falls:

Available July 1, 1876	$2,947 50
Expended in 1876 and 1877	2,947 50

Act of July 31, 1876.

Engineering, maintenance, and repairs:

Available July 31, 1876	$18,000 00
Expended to March 3, 1877	10,081 49
Available March 3, 1877	7,918 51

Repairs of Georgetown reservoir:

Available July 31, 1876	$4,000 00
Expended to March 3, 1877	4,000 00

GENERAL SUMMARY.

In closing this report and my connection with the office, which has extended over nearly six years, I take a pardonable pride in reverting briefly to the work that has been accomplished in the way of improving and beautifying the various public reservations in the national capital. Many of these reservations were commons and public dumping-grounds when I assumed the duties of the position.

The reservations, the entire improvement of which was made by this office, number 25, and contain an area of 94⅝ acres. The improvements consisted of draining, laying of water-pipes for irrigation and to supply fountains, grading, sowing of grass-seed, setting out trees, making walks and roads, and inclosing with either post-and-chain or iron fence. They are situated as follows, viz:

Triangular reservation corner Pennsylvania avenue and Twenty-first street.
Triangular reservation corner Pennsylvania avenue and Nineteenth street.
Triangular reservation corner Pennsylvania avenue and Eighteenth street.
Triangular reservation corner Pennsylvania avenue and Seventh street.
Triangular reservation corner Pennsylvania avenue and Twenty-sixth street.
Triangular reservation corner Massachusetts avenue and Fifteenth street.
Triangular reservation corner Massachusetts avenue and Seventeenth street.
Triangular reservation corner Massachusetts avenue and Tenth street.
Triangular reservation corner Massachusetts avenue and Eleventh street.
Triangular reservation corner Massachusetts avenue and Sixth street.
Triangular reservation corner New York avenue and Thirteenth street.
Triangular reservation corner New York avenue and Twelfth street.
Triangular reservation corner New York avenue and Tenth street.
Triangular reservation corner Maryland avenue and First street, E.
Triangular reservation corner Missouri avenue and Third and Sixth streets.
Triangular reservation corner Maine avenue and Third and Sixth streets.
Circle, Rhode Island avenue and Thirteenth street.
Circle, Massachusetts avenue and Nineteenth street.
Judiciary Square.
Lincoln Square.
Armory Square.
Rawlins Square.
Farragut Square.
McPherson Square. (Formerly Scott Square.)
Monument Grounds.

Those improved in part contain an area of more than 145 acres, and are as follows

Mount Vernon Place.
Smithsonian Grounds.
Grounds around Executive Mansion.
Lafayette Square.
Franklin Square.
Reservation, North Carolina avenue and Seventh street, E.

In addition, the office has erected, complete, in the public reservations above enumerated, 10 fountains and bowls and 18 drinking-fountains.

The number of seats purchased and manufactured and placed in the grounds is 975.

LODGES.

The lodges erected for the convenience of the watchmen and public are five in number, and are located in Lafayette, Franklin, Judiciary, and Lincoln Squares, and the Smithsonian grounds.

LAKES.

Two lakes were made in the Monument grounds—one containing an area of 6 acres and 1,615 square feet, and the other 4 acres and 7,310 square feet, and their banks were sodded and paved with cobble-stones.

VASES.

The number of vases placed in the public reservations is 18, two of which are the massive bronze vases in Lafayette Square.

ROADS AND WALKS.

The number of square yards of roads and walks laid is as follows:

Gravel walks	33,583
Asphalt	6,805
Gravel roads	57,215

EXECUTIVE MANSION.

The repairs to the Mansion have been: Putting on new copper roof, remodeling the East room, constructing and enlarging the private stairway, and building three baths and closets complete, besides many minor repairs that were necessary to keep the Mansion in thorough order.

STATUES AND PEDESTALS.

During this time I served on the commission to erect the bronze equestrian statue to Major-General Winfield Scott; procured and erected the pedestal for the same.

Served on the commission which procured the bronze statue to Major-General J. A. Rawlins; designed, procured, and erected the pedestal for same.

Designed, procured, and erected the pedestal to the Lincoln Group in Lincoln Square.

Designed, procured, and erected the pedestal to Major-General J. B. McPherson in McPherson Square.

Restored the bronze statue of Jefferson, (so long in front of the Executive Mansion,) procured pedestal for same, and placed both in Statuary Hall, Capitol-building.

BRIDGES.

Chain Bridge.—A substantial wrought-iron bridge, 1,352 feet long, was built over the Potomac at the site of "Chain Bridge." It consists of six spans of 172 feet each and two spans of 160 feet each.

Anacostia Bridge.—A substantial iron and masonry bridge and a causeway was built over the Anacostia River at the site of the Navy-yard Bridge. It consists of twelve spans of 102 feet each, one draw-span of 36 feet, and 440 feet of causeway, making a total length of bridge and causeway of 1,700 feet.

WASHINGTON AQUEDUCT.

District of Columbia 36-inch main laid from the distributing reservoir to the intersection of L street and New Jersey avenue, a distance of 22,000 feet.

District of Columbia 30-inch main laid from the 36-inch main at the intersection of L street and New Jersey avenue to the United States 30-inch main at the intersection of New Jersey avenue with Massachusetts avenue, a distance of 1,875 feet.

District of Columbia 20-inch main laid from the end of the United States 20 inch main at the intersection of New Jersey avenue with North B street, along the center of North B street to its intersection with Eleventh street east, a distance of 4,100 feet.

A new office built in Georgetown, at Aqueduct street and Rock Creek.

High-service reservoir in Georgetown finished with an ornamental iron cornice and the dome covered with pebble stucco, and an ornamental wrought-iron fence built on Road and High streets.

Distributing-reservoir, 44 acres, finished. The influent and effluent gate-houses and stair well-house were finished. The auxiliary gate-house was built. The central gate-house was built and a 48-inch cast-iron main laid therefrom to the effluent well-house. The excavation of the bottom of the reservoir was finished to a level of 135 feet above datum, and a wooden fence 8 feet high built entirely around the reservoir, a distance of 5,875 feet.

Stone bridges Nos. 1 and 2 were finished by setting coping, and bridges Nos. 3 and 4 were finished by setting cut-stone parapets and coping. The roadway over bridges 3 and 4 ("Griffith Park" and "Cabin John") were covered with a substantial asphalt pavement.

The roadway over the conduit was partially macadamized. Four ventilators were built along the conduit, and a telegraph was erected from Georgetown to Great Falls and connected with a printing instrument at the falls, each reservoir, and the office in Georgetown.

At Great Falls a stone dwelling was built for the gate-keeper, a wrought-iron truss roof and galvanized iron cornice was erected on the gate-house, and the Government lands, 5½ acres, were inclosed with a substantial wooden fence.

At the receiving reservoir, also at the distributing-reservoir, a brick dwelling was built for the gate-keeper. The grounds surrounding the dwellings at Great Falls and the distributing-reservoir were graded and ornamented with trees and plants.

The final return of the accounts ending March 3, 1877, was forwarded for settlement on March 12.

A notice from the First Comptroller stating that the account had been examined and found correct was received May 1, 1877, and a statement that the account had been closed on the books of the Treasury was received June 14, 1877, thus completing the entire disbursement without the suspension or disallowance of a single item.

I am, general, very respectfully, your obedient servant,

O. E. Babcock,
Colonel of Engineers.

Brig. Gen. A. A. Humphreys,
Chief of Engineers U. S. A.

REPORTS OF LIEUTENANT COLONEL THOMAS LINCOLN CASEY, CORPS OF ENGINEERS, FOR PART OF THE FISCAL YEAR ENDING JUNE 30, 1877.

K K 2.

IMPROVEMENT AND CARE OF THE PUBLIC BUILDINGS AND GROUNDS IN THE DISTRICT OF COLUMBIA.

OFFICE PUBLIC BUILDINGS AND GROUNDS,
Washington, D. C., June 30, 1877.

GENERAL: In accordance with Special Orders No. 44, Paragraph 8, from headquarters of the Army, A. G. O., dated February 27, 1877, I relieved Col. O. E. Babcock, Corps of Engineers, on the 3d March, 1877, of the charge of public buildings and grounds, and other public works in the District of Columbia.

Understanding that Colonel Babcock has reported the operations upon public buildings and grounds up to the time he was relieved of their charge, I confine this report to that portion of the fiscal year ending June 30, 1877, subsequent to the 3d March, 1877.

LAFAYETTE SQUARE.

This park, from its situation, is probably the most frequented of all the public parks in Washington, and the improvements made therein the past few years, and the choice varieties of evergreen and deciduous trees planted within it—many of them perfect specimens of their kind—make it all the more attractive. Such care as was practicable has been bestowed upon it; flower-beds have been planted, pipes repaired, the approaches to the lodge have been screened by trellis-work intended to support trailing vines; the interior arrangements of the lodge have been repaired, the walls color-washed; the lawn mown repeatedly, and the walks kept clear of grass and rubbish. The surfaces of the lawns in several places have been exhausted, and the finer grasses have suffered in consequence, being replaced in many instances by varieties of coarser grass, weeds, &c. The lawns require to be top-dressed with proper fertilizers and resown. The margin of the walks in this as in all other reservations open to the public, has been abraded and their outlines damaged by trespassers, induced, apparently, by the roughness of the gravel-walks, and their muddy condition in the spring, which prompts walking on the grass-borders. In this way paths have been widened from 1 to 5 feet, the original outlines defaced or their symmetry greatly marred. The remedy for this evil seems to be the use of some material that will give an improved surface to the walks, and some kind of park curb to define them and preserve their uniformity. Wherever these trespasses have become very marked, measures have been taken to obviate them and prevent their recurrence, but as long as the roadways present harsh uneven surfaces, as almost all made of gravel do, it will require a considerable outlay to keep the turf bordering them in a satisfactory condition.

The underdrainage of this park is generally in a very unsatisfactory condition. The wooden box-drain, the outlet of the lateral tile-drains, and waste-pipes from drinking fountains require attention after almost every hard rain. The traps for surface drainage, although constructed

at the lowest points, are insufficient in number, causing the water to overflow the surface of the walks. To remedy this, the wooden trunk-drain should be replaced with terra-cotta pipe of larger diameter, with cemented joints, and more traps constructed to carry off surface drainage. The sewer traps should be disconnected from the tile-drain and connected with main drains of 6-inch terra-cotta pipe.

The central gate on the north of the square requires raising, and the walks filling above the grade of the pavement.

Several of the present flower-beds in this park are so deeply shaded as to render them impracticable for plant growth, and they will be dug up and sown down in grass-seed or sodded.

The watchman's lodge in this park requires some repairs, which cannot be made with present appropriations.

The large antique vases in the ground might be made available for flowering plants, by having cast or sheet iron cases made to fit them, and it is proposed to lay out flower-beds at their bases and in the inclosures around the Jackson statue.

The appropriation for the improvement of public grounds is not sufficient to carry out even the most necessary of the repairs above indicated, but attention is called to them in the hope that their desirability may be recognized.

FRANKLIN SQUARE.

This park has been very much improved, and, as a popular place of resort, is probably only second to Lafayette Square.

Although it does not contain as many nor as valuable specimens of trees as the former park, yet the varied undulations of the ground, and the manner of planting the shrubbery, will eventually, by proper management and judicious additions, produce very pleasing effects. The proximity of this reservation to the Franklin and other schools, while affording unquestionable benefit by its shaded walks and pleasure grounds to the scholars and other children frequenting it, for that reason entails much additional labor to keep it in order.

During the spring the flower-beds were dug, manured, and planted, and the borders of many sodded; dead trees were removed, and the lawns mown and carefully tended, as were also the gravel walks. The water and drain pipe connections with the fountain, and the lodge were repaired, and the hemlock hedges covering approaches to the lodge carefully trimmed and gaps in them filled.

The following improvements could be made in this reservation with great effect. The margin of the walks, which have been much injured by trespassers, heavy rains washing the gravel from sloping surfaces, in some instances forming ruts and gullies, which, when repaired, are again washed out by succeeding rains, could be re-outlined from the original plan and supplied with a coating of asphalt or concrete, guttered, curbed, &c., and traps placed at all low points for surface drainage. The lawns require top-dressing, and in some places should be sown with good grasses, weeds having made considerable inroads upon the lawns.

The granite copings to the springs which supply the Executive Mansion, &c., are at present above the surface of the lawns, and should be lowered to the grade. The granite coping to the fountain in this park is constantly spreading and should be reset and reclamped so as to prevent leaks in the future. One of the main gates on I street is broken and should be repaired, as should also the watchman's lodge.

JUDICIARY SQUARE.

The improvement of Judiciary Square was commenced in November, 1873, and has been continued with such appropriations as were available.

At the present time the reservation, with the exception of the portion occupied by the old jail, the removal of which is not under the control of this office, is in an advanced stage toward final completion. The walks and roads have been laid out, the lawns formed, and a large number of evergreens, deciduous trees, and flowering shrubs have been planted. The watchman's lodge on the main roadway and other improvements of a permanent character have been completed.

This park has proven an agreeable place of resort for residents of this part of the city, and is daily visited by large numbers of persons. When the trees planted have attained a more advanced growth, and the improvements at present in contemplation have been fully carried out, it will not be second to any other park in its advantages.

During the spring a number of paths worn upon the lawns were dug up, sown down in lawn-grass, and staked and wired to prevent further travel upon them. Gravel walks were constructed as entrances to the lodge, their borders graded and sodded, and unfinished portions of the lawn around the lodge improved. A cobble-stone gutter, 20 inches wide, was constructed on margin of walk from E street to Louisiana avenue, and a sewer-trap connected with one of the main drains passing through this park was placed at the lowest point of the walk to receive surface water. The gravel walks and roadways were generally out of repair when I assumed charge of public grounds, and were improved as far as practicable with gravel removed from the parterre in front of the Executive Mansion.

From an accidental breakage of the sewer-pipes connected with the lodge the foundation settled under its center, necessitating the taking down of the bowls and stand with it.

The break was repaired in a thorough manner and the opportunity embraced to make desired modifications in the water supply. The lawns in the reservations were mown as frequently as the force at my disposal would permit.

Much difficulty has been experienced in keeping the walks of this park in a serviceable condition, every heavy rain causing the traps to become filled with sand and gravel and washing deep gullies in the roadways. To prevent this the walks and roadways should be coated with an asphalt or other fixed covering, curbed and guttered, and sewer-traps constructed for surface drainage. The carriage-roads should be supplied with a coating of screened gravel, properly curbed and guttered, and furnished with suitable traps. The great cause of washing in this park is the insufficiency of gutters and of traps, the original plan calling for 47 traps, while 17 only have been constructed.

The water from the drinking-fountains in this, as in all other reservations, when exposed to strong winds, is blown on to the gravel for several feet around the post, rendering the approaches wet and disagreeable; and this trouble is augmented by persons using the fountains throwing water on the ground. To remedy this all drinking-fountains should be flagged, curbed, &c., or concrete pavements laid around them with proper outlets for the overflow.

The aspen, poplars, and soft-wooded maples growing above the grade in the southern portion of the park should be removed, and their places supplied with trees of a more ornamental character. A number of flowering shrubs, &c., are required to complete the planting of this park, and a greater number of seats ought to be provided for the accommodation of the visiting public. As far as means will allow, these will be supplied as the improvement of the ground progresses. This reservation having been for many years used as a dumping ground by contractors,

the soil is mostly clay, and when trees and shrubs are planted, large holes have to be dug and filled with good earth, to insure their growth. The lawns require liberal top-dressing of compost and other fertilizers, which will be supplied as far as practicable.

GROUNDS ABOUT THE EXECUTIVE MANSION.

These grounds are bounded by Fifteenth and Seventeenth streets, Pennsylvania avenue, and north B street. Including the site of the State, War, and Navy Departments building, as completed, and the ground occupied by the Treasury, the park would cover an area of about 80 acres. The northern portion, and the inclosure south of the Executive Mansion, have been partly improved and planted. The improvement of the southern portion, in the immediate vicinity and in full view of the mansion, progresses very slowly, and consists mainly in grading such soil, clay, and refuse material as may be deposited therein by contractors and others, who find this a convenient dumping-ground. To properly complete the grading of this reservation would require a large appropriation to purchase a sufficient quantity of soil; after which the other improvements could be vigorously pressed forward to completion.

To continue the improvement of the inclosed portion of this park, the gravel walks should be concreted and curbed, and the embankments, caused by lowering the grade of Executive avenue, should be reduced. The surplus soil, &c., thus procured, would materially assist in grading the south portion of the grounds. The lawn immediately in front of the mansion has been relaid in grass, and mown as frequently as the funds appropriated would admit. A plan for the permanent improvement of reservation is now being prepared.

The greenhouses require extensive repairs; the wooden superstructure of the main conservatory is much decayed and requires rebuilding. A substantial floor, consisting of brick arches supported by wrought-iron rolled beams covered by cement concrete, was constructed in 1873, at which time estimates were also prepared for an iron superstructure to replace the present partially decayed structure, which, however, was never commenced for want of means. It is now proposed to renew the wooden superstructure at as early a day as practicable.

During the spring an increased number of seats was introduced into the grounds south of the Executive Mansion for the accommodation of the visitors who come weekly to hear the concerts of the Marine Band.

WASHINGTON CIRCLE.

(At the intersection of Pennsylvania and New Hampshire avenues.)

This reservation is not in the condition its prominence deserves as regarding improvement and ornamentation. The walks, as originally laid out, were formed of unscreened gravel, very unpleasant for pedestrian passage.

In 1874 the walks were taken up and relaid with screened gravel and rolled, the mound at the base of the statue regraded and enlarged, water-pipes connecting with the Government main were introduced, and brick gutters were laid around the mound, connecting with a trap from which a line of four-inch pipe was laid to the street sewer. The trees were trimmed to afford a partial view of the statue, and seats placed in the circle. Since that time no marked improvement has been made there.

During the spring the lawns were placed in good condition, and the usual care and attention bestowed upon them. The trees originally placed in the circle were principally of rapid growth, and unsuitable to

the present idea of shrubbery ornamentation. They were thicky planted, and at present conceal in many directions the statue, which is the main feature of the circle.

The rubble drains are unserviceable, the grass lawns are overrun with garlic, the margins and corners of the walks have nearly lost all outline from continual trampling upon the grass, and, altogether, this reservation shows the need of improvements which the appropriations at my disposal will not warrant me in making. It is proper to state, however, that to suitably improve this park the trees of large growth and of a character not adapted to small grounds should be removed, wherever they now obstruct views of the statue from the approaches; the ground should be plowed or trenched, the garlic picked out, and the soil enriched with good manure, regraded, sodded or sown down in lawn-grass seed. The walks should be formed of concrete or cement pavement, which, when properly laid, is more durable and less liable to get out of order than gravel; fenced with park curbing, guttered, and provided with traps.

The park settees at present in this circle are located on margins of walks, and fastened to stakes driven in the ground to prevent their removal. In this, and indeed in most all parks containing seats, the latter have worked loose in the ground, so that the seats appear to occupants very unstable. This will be remedied as far as means at my disposal will permit.

A drinking-fountain placed in this circle would be a further public convenience, and it is proposed to plant flower-beds in the mound at the base of the statue and at other points where they will prove attractive.

MC PHERSON PARK,

(Vermont avenue, between I and K streets.)

This reservation has been improved with concrete walks, water, and gas, and handsome lawns formed; a drinking-fountain constructed on one of the walks and placed in suitable position. The statue of General McPherson, erected in the center, is surmounted by 4 semicircular beds, upon which handsome vases have been placed, filled with an assorted variety of foliage and flowering plants.

During the present season these have been carefully attended, as far as the small force available for general work could perform that duty.

Prior to inclosing this reservation with a post-and-chain fence, Vermont avenue passed through it, bordered by soft-wooded maples. The trees have now reached maturity, forming diagonal lines through the grounds, and, until removed, will effectually prevent the accomplishment of any systematic ornamental planting of the reservation. The line of maples should be broken, and the planting of ornamental trees suitable for a park of this character, commenced some time ago by disposing groups of evergreens and shrubs at the open ends of the park, should be continued. The semicircular beds around the statue should be supplied with flowering plants, beds of which should also be formed on the lawns in a line with the avenue, if it is retained.

FARRAGUT PARK,

(On Connecticut avenue, between I and K streets.)

This reservation is very similar in appearance to McPherson Park, excepting an open space reserved in the center for the projected statue

of Admiral Farragut, and which, at this time, is used as a bed for flowering plants. This park compares favorably with others, as regards permanent improvements, but the lawns require top-dressing, and the concrete walks minor repairs. They should be curbed, guttered, provided with traps for surface drainage, and inclosures should be made for seats in the manner suggested in another portion of this report. It would also improve the looks of the ground to place in it vases for flowering plants, similar to those in other squares. It is proposed to make flower-beds at suitable points on the lawns, and to plant a number of trees and ornamental shrubs, which are required to complete the original design. The roadway through it, upon the axis of Connecticut avenue, should be removed, and suitable paths for the accommodation of foot-passengers laid down in its stead.

RAWLINS PARK,

(New York avenue, between Eighteenth and Nineteenth streets.)

This park has all the improvements that have been put upon other grounds, having all necessary gas and water pipes, concrete walks, fountains, vases, seats, shrubbery, and flowering plants. From its location it does not attract very general attention, but is a pleasant place of resort, and has received the same amount of attention that has been bestowed upon other reservations. It would be further improved, however, by curbing and guttering the walks, providing them with traps for surface drainage, dressing the lawns with compost, and placing an additional number of vases and seats in the grounds. With the exception, however, of top-dressing the lawns, it is not believed that the improvements suggested for this park are as imperative as those recommended for other squares.

MOUNT VERNON PLACE.

(Intersection of Massachusetts and New York avenues.)

These grounds were improved in part by the board of public works of the District government, concrete roadways were constructed in a line with the streets and avenues, and the sidewalks parallel thereto were flagged and curbed, and an ornamental iron fountain of artistic design placed on a circular mound in the center. The lawns are in good condition, having been mown and kept in order, as have also the walks and shrubbery. The park is inclosed with a post-and-chain fence, and has settees placed on the walks. It has not, however, been drained.

The following improvements are recommended for this reservation:

Thorough drainage, the contraction of the mound at the base of the fountain, and the formation of a narrow walk for the accommodation of pedestrians around it. All the roadways of the park intersect at this point, and persons crossing them must necessarily step on the mound to keep out of the way of passing vehicles, in consequence of which the grass surface is constantly trodden down and destroyed. This would be obviated by the construction of a foot-walk.

This park is too much cut up with roads, and it is submitted that the removal of the roadways upon the axis of New York and Massachusetts avenues, throwing the spaces now occupied by them into lawns, would be a desirable improvement.

The lawns require top-dressing, and a number of ornamental trees and shrubs are required for the now too open grounds. A number of large

vases for flowering plants, if tastefully located in these grounds, would greatly enhance their attractiveness. The number of settees now there is insufficient for the wants of the public.

CIRCLE AT THE INTERSECTION OF VERMONT AND MASSACHUSETTS AVENUES AND FOURTEENTH AND M STREETS.

This reservation was improved and planted in 1872 and 1873, and has required no further labor since than the ordinary care and protection extended to lawn, trees, and shrubbery. The plants and trees in it are unusually healthy and vigorous, which is ascribed to the thoroughness with which the ground was drained, and the subsoil incorporated with good rich earth at the time it was first improved. It is supplied with rustic stone seats and settees, and has a terra-cotta fountain-basin in its center. During the spring the grounds were put in a complete state of order, and flower-beds dug and planted with an assorted variety of flowers, as were also the two vases within the inclosure. The walks originally laid down have, by constant use, worn rough and uneven, and require to be resurfaced, and their outlines should be defined and preserved by park-curbing. In this, as in all other improved public reservations in this city, the points or corners of the lawns become abraded and disfigured by persons stepping on them in passing from one walk to another, so that much labor is necessarily expended in re-lining and re-sodding them. Ornamental metal guards placed on the margin of the plots at their angles would prove an effectual remedy, and at the same time add to the appearance of the grounds.

This circle has been selected by the commission appointed by Congress for the site of the statue of General George H. Thomas. It is probable that after the erection of this statue the grounds will have to be entirely remodeled.

CIRCLE AT THE INTERSECTION OF NEW HAMPSHIRE, CONNECTICUT, AND MASSACHUSETTS AVENUES.

This reservation is underdrained by pipes leading to a semicircular main drain connected with the main sewer on Nineteenth street. It has also been improved by gas and water, and street-washers have been located in different parts of the circle. The walks are covered with concrete, with seats placed in suitable positions, and a variety of trees and shrubs have been planted in it.

During the spring the grass in this park was mown and raked repeatedly, and blue-grass and winter-rye sown on such portions of the lawn as had not good sod. Dead shrubs were also replaced by others of healthy growth when practicable. The concrete walks require resurfacing and other repairs, and should be curbed, guttered, and provided with trap-sewers for surface-drainage. The lawns need top-dressing of compost or other fertilizer, and in some places, having settled, the depressions require raising to grade by a coating of good soil.

It is understood that by the plan adopted for this reservation a fountain was intended for its center, and the necessary water and wash pipes were laid. In laying off the ground a circular space, 60 feet in diameter, was reserved for the proposed fountain. From the commanding position of this reservation a fountain of sufficient size, provided with suitable jets, would be very conspicuous from the surrounding avenues, and would prove a most attractive feature in the general ornamentation of the park. A number of ornamental trees and shrubs are required to complete the original design, as are also vases for flowering-plants.

THIRTEENTH-STREET CIRCLE.

This is one of the largest of the circles in Washington, and is situated in one of the most attractive sections of the city. It has been thoroughly subdrained, necessary water and gas pipes introduced, the walks laid out, graveled and concreted, a number of shade and ornamental trees and shrubs planted, a fountain-basin thirty feet in diameter with rock-work center, intended as a receptacle for semi-aquatic plants, constructed, four ornamental iron vases for flowering plants placed in suitable positions, and a number of ornamental park-settees placed on the walks for public accommodation. The circle itself is inclosed with a post-and-chain fence, which includes eight ornamental iron lamp-posts.

The reservation received the usual attention in the spring, such as general cleaning, repairing of walks, removal of dead shrubs, &c. The lawn also had necessary care bestowed upon it.

The walks in this circle should be curbed and properly guttered and provided with traps to receive surface-drainage. Suitable paved spaces should also be formed for the seats, so as to prevent the surrounding grass from receiving injury by persons using the seats trampling upon it. Upon this subject I shall remark more at length further on. The lawns in some places are too low, and should be brought to a proper grade with good soil and resown with grass-seed. It is understood that this circle when first improved was cut down several feet, the good soil saved, and with several hundred loads purchased, applied to the finished grades. It proved, however, to be much less in quantity than seems to have been required for this purpose, and in this as in other public reservations, the future success of the lawn surfaces will depend in a great measure upon liberal use of top-dressing for a succession of years.

The ground falls from the center to the circumference of the circle, and possesses many ornamental advantages. Its topography leads, however, to this disadvantage: that during the bad weather of winter months the flag pavement surrounding it is constantly saturated with water shed from its surface, which, forming into ice, makes travel difficult and often dangerous. To remedy the difficulty, gutters should be formed around the margins of the circle with a sufficient number of sewer-traps to carry off the water. A number of trees, shrubs, &c., are required to complete the planting of this circle, and flower-beds will hereafter be formed on the lawn surfaces.

RESERVATIONS BETWEEN THIRD AND FOUR-AND-A-HALF STREETS, AND MAINE AND MISSOURI AVENUES.

This reservation formerly composed two triangles divided by the canal, the bed of which was filled in and added to the reservation, the low grounds in it raised, and the whole graded and thoroughly drained. Water and gas pipes have been introduced. The park has been inclosed with a post-and-chain fence, roadways and walks constructed, the lawn set in grass, and choice ornamental trees and shrubs planted. Two drinking-fountains have also been introduced.

This is the commencement of a chain of parks extending from the Capitol to the Washington Monument, embracing the grounds south of the Executive Mansion. The plan of making a connected park in this way was proposed by Downing, and approved by President Fillmore. If carried to completion it would embrace the reservations intervening between the Capitol and Executive Mansion. Such a park would be

one of the most attractive features of Washington. In my judgment when work is commenced on the unimproved ground in this chain, as on other unimproved reservations in the District, it should be conducted in a most thorough and systematic manner so as to do away with frequent repairs. As regards the improved portions of the reservation, the walks should be coated with asphalt or Portland-cement pavement, with borders well defined, and guttered, and provided at all low points with suitable traps for surface drainage. One of the greatest wants of these grounds is a sufficient number of traps to carry off the water of continued rains. The lawns need constant attention and an additional number of ornamental trees; and shrubs will be planted in the reservation between Third and Four-and-a-half streets to fulfill the plan adopted for its improvement.

RESERVATION BETWEEN FOUR-AND-A-HALF AND SIXTH STREETS, MAINE AND MISSOURI AVENUES.

This reservation was originally divided by the old line of the canal into two parcels of land, one of which was used by the Agricultural Department, as an experimental garden, and subsequently passed under the control of this office. It has been only partly improved, that portion of ground south of the main roadway having been graded and drained, soiled, and gas and water pipes introduced. Walks have also been laid out and graveled, lawns sown in grass, and a number of trees and shrubs planted. The ground north of the main roadway comprising the largest part of the park has been partially graded and surfaced with soil, and the road-beds of some walks excavated. The embankment next Sixth street has been sodded. A post-and-chain fence incloses the reservation.

The further and final improvement of this park should be completed as early as practicable. Its close proximity to the Capitol and other large improved parks makes its present neglected condition particularly conspicuous.

During the spring such labor as was at my disposal for the purpose has been employed in looking after the lawns, walks, and shrubbery, but it was not sufficient to ameliorate, in any marked degree, the condition of the ground.

ARMORY SQUARE, BETWEEN SIXTH AND SEVENTH STREETS WEST, AND B STREETS NORTH AND SOUTH.

This reservation has received considerable improvement, though a portion of it, in plain view from one of the principal streets of the city, still needs draining, sodding, and ornamentation.

The grading of a greater portion of the ground has, however, been completed, water and gas pipes have been introduced, lateral and main drains laid connecting with Seventh-street sewer, walks and roadways connecting with those of the Smithsonian grounds laid out and graveled, a fountain constructed, lawns set in grass, and the ornamentation of the grounds considerably advanced; seats have been placed on some of the walks, but more are required. The grass has been mown several times in this reservation, paths worn in the sod by trespassers have been dug up, sown with grass-seed, staked and wired, and a portion of the lawn destroyed by vehicles hauling specimens from the Centennial Exhibition to the Armory building repaired. One of the first improvements should be the grading of that portion of the ground now without

grass, and other material should be substituted for the gravel now on the walks and roadways, and they should be curbed and guttered, and provided with proper means for complete surface drainage. The lawns also require top-dressing.

The terrace slope on Sixth street is in a very unsatisfactory condition, the earth during heavy rains washing down on the street-pavement. This should be obviated by grading and sodding. A temporary roadway, although not provided for in the original plan, should be constructed from B street south to the Armory building, in order to prevent future damage to the principal drives and lawns by the passage of heavy teams to the building, which is now occupied by the Smithsonian Institute. Drinking-fountains placed on the main walks are much needed, and a watchman's lodge provided with suitable conveniences would prove a further public benefit.

SMITHSONIAN GROUNDS BETWEEN SEVENTH AND TWELFTH AND B STREETS NORTH AND SOUTH.

This reservation, the largest under the control of this office, was one of the first parks in Washington improved and planted, and is one of the most frequented of the public grounds. Although 25 years have elapsed since the plans for its improvement were submitted and approved, numerous causes combined to prevent their being carried out to completion, so that even now much remains to be done before it can be said to be in a finished condition. Among the gravest of these were its location south of the old canal, and its remoteness from the principal improved sections of the city. The appropriations made for its care, with some exceptions, have not sufficed to protect the large area of this park, over 52 acres. There are but two watchmen assigned to these grounds, who are on duty at night; and during the day, with the exception of occasional visits of the Metropolitan police, it has no protection whatever.

In 1874 and 1875 the southern portion of this park was graded and drained, water and gas pipes introduced, and walks and roadways laid out as nearly in accordance with the original plan of Mr. Downing as practicable. The northern portion of the grounds, formerly the line of the canal, was also improved as far as appropriations for that purpose were available. Drains were laid, and gas and water pipes introduced, with suitable connections for irrigation, &c. Trees and shrubs were planted, and a number of settees placed in position for the accommodation of persons visiting the park. The grass of the whole reservation has been mown, cured, and stored, for the use of the public animals belonging to the works. The trees and lawns also received the usual attention in the spring.

To complete the improvement of this park the following work would be necessary: A number of large trees of rapid growth that were planted for the filling out of groups until trees of slow growth, now overcrowded, attained their maturity, should be removed, as also other trees not called for by the plans. The main portion of the ground originally provided with rubble drains, now, from various causes, choked and unserviceable, should be provided with tile and main terra-cotta pipe drains properly located and connected with street-sewers. The roadways and walks should be regraveled, or preferably, coated with material of a more substantial character, properly curbed and guttered, and thorough provisions made for carrying off surface-water.

In the original plan a large fountain was proposed for the center of

this park. A lodge provided with public accommodations is much needed, and should be erected in some suitable locality at an early day.

The lawn grasses are in a great many places worn out and should be replaced; and where necessary, in the newly laid out portions of the park, ornamental evergreens and deciduous trees, &c., should be planted.

The approaches to the main roadway on Seventh street south and Tenth and B streets north, should be paved with Belgium or some other suitable pavement and curbed, as should also the Seventh-street entrances to Armory Square. Asphalt foot-walks from Seventh, Tenth, and Twelfth streets should be carried to the doors of the Smithsonian Institute, estimates for which purpose are submitted with this report.

MONUMENT GROUNDS BETWEEN FOURTEENTH AND SEVENTEENTH STREETS WEST, AND B STREETS NORTH AND SOUTH.

This reservation has been somewhat improved, although much further labor will be required to properly complete the plans prepared for the grounds.

Two of the main roadways have been laid out and partially graveled, and a number of the walks required by the plans have been staked out and graveled. The grading of these grounds has been nearly completed. The marshes, formerly in the northern portion of the park, have been partly excavated and formed into lakes, affording a water-surface of nearly 12 acres, their margins have been sodded and paved to prevent washings and to preserve outlines, excepting the western and part of the northern bank of the western lake, which could not be finished owing to the insufficiency of the appropriation.

Ripp's Island, in the western lake, has been planted and graded. It is the design, in the further improvement of these grounds, to construct rustic bridges connecting the island with the main roadways.

Whenever practicable, trees and shrubs have been planted in these grounds; but, in proportion to what the plans call for, little has been done in this direction.

The nursery grounds have never been laid out, nor have the resources of the garden been fully developed. The ground, lacking improvement, should be supplied with drain and water pipes, and with walks and roadways. The stock of trees and plants procurable from these grounds is very much less than what is needed, and the nursery cannot, in its present condition, furnish more than a third of the young trees and the larger plants that will be required next year.

During the year 40,000 small plants have been distributed, of which 29,000 have been sent out since the 3d of March last. A larger number can be distributed hereafter with the facilities above suggested. The grounds of many State and other public institutions have been decorated with plants and shrubbery sent out from this nursery.

These houses, designed for the propagation of plants, shrubs, &c., for the public parks, generally are located in the grounds known as the Monument Lot. It would be desirable to construct an additional number of propagating and plant houses here, in order to increase the facilities for properly planting the public parks for summer-decorations.

During the time the garden has been under my charge, the work of propagating and cultivating plants and shrubbery has been carried on with diligence. On the reservation proper the grass was mown, but little more could be done on account of its extent and unimproved condition and lack of means to carry forward plans.

The improvements recommended for this park are: the grading and

draining the entire ground; the introduction of gas and water where necessary; the completion of all the roadways and walks called for by the plans in the most substantial manner; the soiling and sowing with grass-seed of all the lawn-surface, and the planting of needed ornamental shrubbery; the introduction of seats on the walks, and of drinking-fountains connected with the spring that supplies the lakes.

Much difficulty has been experienced in keeping out of sight the rank growth of aquatic plants, that, springing from the bottom of the lakes, cover, in the latter part of summer, the entire surface of the water. The only means now available for keeping them out of sight is to mow them repeatedly as far beneath the surface as practicable, and even this measure is of but temporary advantage. The lake-bottoms should be excavated to a proper depth. The western lake should be outlined, paved, and sodded. It is also submitted that it would greatly promote the general effectiveness of the park to prolong Virginia avenue to Seventeenth street west, and to inclose as a third lake a portion of marsh-land lying south of the line of the avenue and between the points formed by the southwest angle of the Monument grounds and the foot of Seventeenth street, dredging the same to a suitable depth, leaving sufficient land between the lake-bed and river for a roadway and trees, the more effectually to divide the inclosed from the larger body of water south of it.

The embankment on the river-front of these grounds during freshets and high tides is constantly being undermined. If means for the improvement of this portion of the grounds were forthcoming, much future damage would be prevented. A low stone wall or riprap to above high-water and grading and sodding the embankment above it would effectually preserve this front at a comparatively small cost. The actual outlines of the water-front of these grounds present a concave line with several deep indentations, while in the surveys made twenty-five or thirty years ago the outline was distinctly convex, with but one large indentation; which illustrates how rapidly the river is encroaching upon the banks.

RESERVATIONS OF PENNSYLVANIA AVENUE.

The small triangle at the intersection of Twenty-sixth street and Pennsylania avenue has been inclosed with a neat iron railing, graded, sodded, and planted with a variety of ornamental trees and shrubs. Besides these, an ornamental vase for flowering plants should be placed in the inclosure.

The reservation on the south side of Pennsylvania avenue, between Twentieth and Twenty-first streets, has been graded, walks laid out, graveled, and concreted, and a fountain-basin constructed of brick-work lined .with Portland cement, and all necessary pipes. This, combined with the general effect produced by well-kept lawns, ornamental shrubs, and flowering plants, makes this small park an attractive place of resort for neighboring inhabitants and pedestrians. It is inclosed with a post-and-chain fence partly supported by four lamp-posts, and has a drinking-fountain at one end. Ornamental iron vases placed in this park would have an additional attraction.

The reservation on the opposite (north) side of the avenue has been inclosed with an iron railing set in a heavy granite coping. The lawns are below grade and in bad condition, have no paths through them, and the trees are of unsuitable character, and too thickly planted. It militates against the attractiveness of the opposite reservation, and should be improved to correspond to it, and thrown open to the public.

The improvement of the triangle on the south side of the Avenue, between Eighteenth and Nineteenth streets, has been nearly completed. The plan adopted was similar to the design of the reservation on the south side of the Avenue, before described, excepting the fountain-basin, which is of rock-work, with pockets on the margin of the basin, and the center of the rock-pyramid for semi-aquatic plants. It has a large Warwick vase, filled with flowering and foliage plants, and rustic seats for the accommodation of visitors.

The triangle on the opposite (north) side of the avenue has been only partially improved. It has been graded, water-pipes introduced, the lawn set in grass, ornamental trees and shrubs planted, the walks graveled, and the reservation inclosed with a post-and-chain fence. A circular space is left in center for a fountain. The walks are provided with seats.

The reservations on Pennsylvania Avenue between Thirteenth and Fourteenth streets, located as they are in a prominent business part of the city, should be representatives of our small parks. They now present, however, a neglected appearance, and by no means favorably compare with parks of similar character that have been recently improved.

To suitably improve them, the grounds should be thoroughly trenched, drained, regraded, manured, and set in lawn-grass. Walks should be laid out and supplied with seats, and water introduced. Fountains, vases, and flower-beds would add to the attractiveness of these parks, and, where required, ornamental evergreens and flowering shrubs should be planted.

During the spring, the small triangular reservation at the intersection of Pennsylvania avenue and Seventh street was partly improved. Park-curbing was placed around this reservation, the fence was straightened, the trees were trimmed, and lawns resodded where required. A few flowering trees and shrubs and a vase for flowers should be introduced.

The reservations on New York avenue and Thirteenth street, on New York avenue and Twelfth street, and New York avenue and Tenth street, have been inclosed and partially improved. In the latter a fountain has been introduced, the waste-pipes of which are, however, out of repair. The triangle at the intersection of New York avenue and Sixth street is occupied by the Abbott school-building. That at the intersection of the New York avenue and First street has not been improved.

Of the reservations of Massachusetts avenue, the one at Twentieth street has not been improved. Those at the junction of Massachusetts and Rhode Island avenues, (east and west of the equestrian statue of General Scott,) have been graded, soiled, sown in grass, and suitable trees and shrubs introduced, care having been taken, in planting, that they should not obstruct the views of the statue from the avenues and streets. The open spaces in the centers were designed for flower-beds, and ornamental iron vases should be placed in them for flowering plants. These reservations have not been drained, neither water nor waste pipes have been introduced, the surface-soil is not more than 6 inches deep, and they require annual top-dressing to keep the turf in good condition. They have been inclosed with post-and-chain fences.

The small circle at the base of the Scott statue has been graded to form a mound, drained, water-pipe connections with good globe-valve attachments had with the main running through the circle; four ornamental evergreens and flower-beds planted; park-curbing and a brick gutter, with traps, have been placed around the margin of the mound, which is further improved by a flag-pavement.

The triangles on Massachusetts avenue between Tenth and Twelfth streets have been improved. When the trees and shrubs introduced some years ago are fully grown, and some further minor improvements made, they will be very attractive. They are already inclosed with post-and-chain fences, are supplied with drinking-fountains and seats, and ornamental iron vases; which latter, however, should be increased in number. In improving these triangles, provision was made for the introduction of fountains.

The tiangle on Massachusetts avenue and Sixth street has been inclosed with a light wrought-iron railing, graded, set in grass, and supplied with ornamental trees and shrubbery. It should be further improved by a fountain, vases, and walks.

The small triangular reservations on Massachusetts avenue between Third and Fourth streets, have been inclosed, soiled, sodded, and supplied with trees. These triangles were improved by the District government and subseqently turned over to this office. Further improvements should consist in the introduction of vases for flowering plants, and the location of a drinking-fountain at the apex of one of the triangles.

The following reservations have not been improved; a number of them are above grade, and nearly all are at present street surfaces:

New Jersey avenue and Second street east.
Delaware avenue and Second street west.
Delaware avenue and First street east.
Maryland avenue and Third street east.
Virginia avenue and Fourth street southwest.
Virginia avenue and Eighteenth street west.
Virginia avenue and Twenty-fourth street west.
Virginia avenue and Twenty-fifth street west.
Virginia avenue and Fourth street east.
Virginia avenue and Ninth street east.
Virginia avenue and Twelfth street east.
South Carolina avenue and Fourth street east.
South Carolina avenue and Sixteenth street east.
Georgia avenue and One-half street west—two triangles.
Georgia avenue and Second street west—two triangles.
Georgia avenue and One-half street east—two triangles.
Georgia avenue and Ninth street east.
Georgia avenue and Eleventh street east.
Georgia avenue and Seventeenth street east.
Water street and One-half street west.
Water street and Fourteenth street east.
Water street and Fifteenth street east.
South Capitol street and I street south.
South Capitol street and E street south.
First street west and D street south.
First street west and L street south.
First street west and H street south.
Sixth street west and N street south.

And other reservations not yet passed to the control of this office from the District government.

I have heretofore referred to the desirability of replacing the present gravel walks with material of a more suitable character, such as compose asphalt pavement, or the many varieties of artificial stone. Its first cost is greater, but when the labor annually expended in repairing washes and in keeping walks free of weeds and grass, and the fact that with a smooth, unyielding surface, dry all times, the gravel offering every temptation for pedestrians to walk upon and destroy the grass-borders, are considered, it is very patent that the Government would annually save large sums by the substitution. Experience has demonstrated the impossibility of preventing persons frequenting paths from

destroying the sod in the vicinity of seats which, if placed upon semi-elliptical spaces on the sides of walks, would obviate this grave objection of seats in public grounds.

Since I assumed charge of this office neither the Chain nor Navy-Yard bridges have needed much repair. The Chain Bridge will soon require an entire new floor, and the entire work painting. An estimate of the cost of this work is submitted.

Permission has recently been given the Washington and Georgetown Gas Company to lay a main over the Navy-Yard Bridge, in order that gas may be introduced into Uniontown. The approaches to that bridge are in a bad condition, and will receive immediate attention to the extent of the limited appropriation available for their repair.

Eleventh street, near the bridge, has a considerable declivity, down which, after severe or long-continued rains, large bodies of water find their way to the abutments of the bridge, and thence into the river, often overflowing the sides of that structure. The street has not the proper sewer facilities for carrying off surface-water, and the approaches to the bridge are, therefore, continually endangered.

The attention of the city authorities has been called to the absence of sewerage in this street, and, it is believed, will give the subject due attention. The riprap approach to the bridge at its northern end is gradually sinking into the mud upon which it was constructed, and will hereafter necessitate the making of considerable repairs.

I understand that the planking on one side of the upper Navy-Yard (Benning's) Bridge was relaid about a year ago. That on the other side will shortly be taken up and new planking substituted.

The spring pipe supplying the Capitol is in good condition, except about 600 feet, which has just become damaged, and which will be immediately repaired. Measures have been taken to regulate the flow of water into the pool on the east front of the Capitol, so that what has heretofore been wasted can be used to supply the steam-boilers in the building. During the summer the spring was thoroughly cleaned and whitewashed, as was also the fence surrounding it.

So much of the line of pipe running from the spring in Franklin Square as supplies the President's House is in good repair; that running to the War and Navy Departments is not in good condition, and a portion of it must, of necessity, be taken up. The cisterns on this line have been thoroughly cleaned, and new pumps placed over each.

The Departmental Telegraph line has been in working order ever since I assumed charge of this office. Estimates for increased appropriations for this line are submitted because, while perhaps sufficient to keep in repair the one wire now in use, the exigencies of the service might at any time demand the equipment of another of the three lines, which could not be done with the means at my disposal.

CONCLUDING REMARKS.

The public grounds in charge of this office are over 200 acres in extent, and require constant attention. The same labor and care bestowed upon the parks and improved squares of other cities must be bestowed upon like grounds in this city, or they will very rapidly fall into disorder, and become blemishes rather than ornaments to the city and desirable resorts for its inhabitants. A force of not less than 50 men should be kept steadily at work from the 1st of March to the 1st of November, and 20 men from the 1st of November to the 1st of March. Such a force of skilled men would very shortly effect a radical change

in the appearance of the improved grounds, and add to the number of improved reservations.

It is a difficult matter to preserve the finer kinds of lawn grasses in this latitude, and only constant manuring, watering in dry weather, under-draining, and careful attention to prevent the growth of weeds and wild grasses will accomplish the desired end. Larger appropriations for fertilizing substances are recommended.

Each of the larger parks, containing lodges, fountains, flower-beds, and statues, should have keepers. They could not only guard the property and improvements, but could also make minor repairs to the walks and grounds.

ESTIMATE OF AMOUNTS REQUIRED FOR THE FISCAL YEAR ENDING JUNE 30, 1879.

Salaries of employés, Public Buildings and Grounds, under Chief of Engineers:

1 clerk	$1,400	
1 messenger	840	
1 public gardener	1,800	
1 draughtsman	1,800	
1 foreman and laborers employed in the public grounds	35,000	
1 furnace-keeper at the Executive Mansion	864	
1 night watchman at the Executive Mansion	900	
1 night usher at the Executive Mansion	1,200	
2 day ushers at the Executive Mansion	2,400	
2 doorkeepers at the Executive Mansion	2,400	
2 drawkeepers at the Navy-Yard and upper bridges	1,440	
1 watchman for Franklin Square	720	
1 watchman for Lafayette Square	720	
4 watchmen for reservation No. 2, (Smithsonian grounds,) at $720 each	2,880	
1 watchman for Judiciary Square	720	
1 watchman for Lincoln Square	720	
1 watchman for Fourteenth and Thirteenth streets circles and neighboring reservations	600	
1 watchman for McPherson and Farragut Squares and neighboring reservations	600	
1 watchman for Rawlins Square and neighboring reservations	600	
1 watchman for Washington Circle and neighboring reservations	600	
1 bridgekeeper at Chain Bridge	720	
1 watchman at propagating garden	600	
		$59,524
Contingent expenses, public buildings and grounds, under Chief of Engineers		1,000
For rent of office, public buildings and grounds		900

Improvement and care of Public Buildings and Grounds in and around Washington:

Filling in and improving grounds south of Executive Mansion	$15,000
Ordinary care and extension of the greenhouses and the nursery	3,000
Ordinary care of Lafayette Square	2,000
Ordinary care of Smithsonian grounds	5,000
Care and improvement of reservation No. 3, monument grounds	10,000
Annual repair of fences	2,000
Manure and hauling the same	8,000
Painting iron fences	2,000
Purchase and repair of seats	4,500
Purchase and repair of tools	1,000
Trees, tree-stakes, lime, whitewashing, and stock for nursery	5,000
Removing snow and ice	1,000
Flower-pots, twine, baskets, lycopodium, &c	1,000
Abating nuisances	500
Care and repairs to fountains in the public grounds	2,000
Improving Stanton Place	10,000
Continuing improvement of Armory Square	8,000
Improvement of reservation between Four-and-a-half and Sixth streets	10,000

Continuing improvement of Seward Place	$5,000	
Improving various reservations	20,000	
Inclosing circle at Massachusetts and New Jersey avenues with iron fence, and improving the same	3,000	
Commencing improvement of reservation No. 17	20,000	
Asphalting walks in the Smithsonian grounds	4,500	
For remodeling of Fourteenth-street circle	5,000	
		$147,500

Repairs, fuel, &c., Executive Mansion:

Repairs of Executive Mansion	10,000	
Refurnishing the Executive Mansion	10,000	
Fuel for the Executive Mansion and the greenhouses	3,000	
Care of and necessary repairs to the greenhouses	6,000	
		29,000

Care and repair of bridges:

Ordinary care of Benning's, Anacostia, and Chain bridges, including fuel, oil, lamps, matches, &c	1,200	
For replanking Chain Bridge	2,500	
For extensive repairs to Benning's Bridge	2,500	
For raising embankments of Anacostia Bridge and riprapping piers and abutments	3,000	
		9,200

For lighting the Executive Mansion and Public Grounds, and fuel for watchmen's lodges and for greenhouses in the nursery:

Gas, pay of lamp-lighters, gas-fitters, plumbers, plumbing, lamps, lamp-posts, matches, and repairs of all kinds; lamps for Anacostia Bridge, fuel for the watchmen's lodges and for the greenhouses in the nursery 20,000

Repair of water-pipes and fire-plugs:

Repairing and extending water-pipes; purchase of apparatus to clean them, and for cleaning the springs and repairing and renewing the pipes of the same that supply the Capitol, the Executive Mansion, and the War and Navy Departments 10,000

Telegraph to connect the Capitol with the Departments and the Government Printing-Office:

For repair and care of the same 1,000

Financial statement, fiscal year ending June 30, 1877.

Title of appropriations.	Amount appropriated.	Amount expended by Col. O. E. Babcock.	Unexpended balance March 3.	Amount expended since March 3.
Salaries of employés, Public Buildings and Grounds	$34,169 51	$21,310 24	$13,165 25	$12,330 48
Contingent expenses office Public Buildings and grounds	500 00	449 30	50 70	50 70
Improvement and care of Public Grounds	30,000 00	23,118 23	6,881 77	6,881 65
Repairs, fuel, &c., Executive Mansion	17,000 00	12,880 85	4,119 15	4,119 04
Lighting, &c., Executive Mansion	19,000 00	12,918 75	6,081 25	5,912 57
Repairs of water-pipes and fire-plugs	5,000 00	4,388 46	611 54	611 54
Repairs of Navy-Yard and Upper bridges	1,000 00	284 00	716 00	100 18
Telegraph to connect Capitol with Departments, &c.	500 00	463 75	36 25	36 10
Pedestal for Thomas statue	25,000 00	....	25,000 00	255 70
Improvement and care of public grounds, (Judiciary Square.)	2,000 00	....	2,000 00	25 33

Very respectfully, your obedient servant,

THOS. LINCOLN CASEY,
Lieutenant-Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

K K 3.

WASHINGTON AQUEDUCT.

OFFICE OF WASHINGTON ACQUEDUCT,
Georgetown, D. C., July 14, 1877.

GENERAL: I have the honor to submit the following report of operations upon the Washington Aqueduct for the fiscal year ending June 30, 1877.

This work was in charge of Col. O. E. Babcock, Corps of Engineers, until March 3, 1877, at which date I was ordered to relieve him.

During the month of July, 1876, the work done was limited to the supervision of the distribution of Potomac water in the conduits, reservoirs, and pipes.

On the 31st of July an appropriation was made by Congress for the fiscal year ending June 30, 1877, as follows:

For engineering, maintenance, and repairs	$18,000 00
For repairs of Georgetown reservoir	4,000 00

The work done under this appropriation has been done by day's work, and the materials used have been purchased in open market.

In August repairs were made to the Potomac dam by replacing the ripraps which had been washed over the dam by freshets.

At the receiving-reservoir the wooden bridge over the waste channel was repaired, a new floor was laid, decayed timber was removed from the trestles and sound timber substituted. The ditches along the conduit between the receiving and distributing reservoirs were cleaned out, and the embankments over the conduit were repaired. At the distributing-reservoir the cast-iron cornices of the gate-houses were painted. At Georgetown repairs were commenced in the high-service reservoir.

In September the embankments over the conduit between Great Falls and the receiving-reservoir were repaired where they had been washed by the rain, and at Georgetown repairs to the high-service reservoir were continued.

In October repairs were again made to the Potomac dam, a freshet in the river having carried away a part of the riprap backing, and repairs to the high-service reservoir were finished. This reservoir had not been in service since December, 1875, when a leak was discovered in the bottom, and the water, in consequence, emptied out. The repairs were commenced as soon as Congress made an appropriation therefor, and they were completed on the 6th of October.

The work done consisted in recalking the joints of the supply-main, cutting out cracks in the concrete bottom, filling them with mortar, and covering the entire bottom with hydraulic concrete from 9 to 16 inches in depth.

As soon as the repairs were done this reservoir was filled with water to a depth of 16 feet; since then it has been in constant use and has not leaked. The ornamental cast-iron cornice surmounting the dome and the wrought-iron fences on Road and High streets were thoroughly painted, and the cornice was sanded.

In November the Macadam road over the conduit was repaired and the ditches were cleaned out. At Georgetown the floor of Rock Creek Bridge was repaired.

In December a leak occurred in the 30-inch main a short distance from the distributing-reservoir. The water was shut off from the main,

the joint was repaired, and the pipe was also banded. At the receiving-reservoir a 2-inch pipe was laid, connected with a spring and a forcing-pump, for the purpose of supplying the gate-keeper's dwelling with water.

In January stone was broken and used on the repairs of the conduit road. At the receiving-reservoir a channel for boats was cut through the ice from the floor to the sluice-tower and kept open during cold weather. In Georgetown the snow was cleaned off the pavements of High and Road streets, in front of the high-service reservoir, and of Aqueduct street in front of the aqueduct office.

From the 20th to the 27th of January permission was given to the officers of the Signal Bureau to use the Washington Aqueduct telegraph during the time that the ice was breaking up in the Potomac River at Harper's Ferry and Great Falls.

In February the embankment over culvert No. 18 was repaired; the roadway over the conduit was also repaired. At Great Falls the contractor for building an iron truss-roof and galvanized-iron cornice on the gate-house finished his work. The contract for the roof and cornice had been entered into with Messrs. Asa Snyder & Co., of Richmond, Va., during the previous fiscal year.

The following is a financial statement to March 3, 1877:

TITLES OF APPROPRIATIONS.

Act of March 3, 1875.

For building iron truss-roof on gate-house at Great Falls:	
Available July 1, 1876	$2,947 50
Expended in 1876 and 1877	2,947 50

Act of July 31, 1876.

Repairs of Georgetown reservoir:	
Available July 31, 1876	$4,000 00
Expended to March 3, 1877	4,000 00
Engineering, maintenance, and repairs:	
Available July 31, 1876	18,000 00
Expended to March 3, 1877	10,181 49
Available March 3, 1877	7,818 51

The above balance has been expended as follows:

In March the iron-work of the gate-house roof, and cornice at Great Falls was partially painted.

At the distributing-reservoir the cast-iron mains, stand-pipes, and stop-cocks in the pipe-vault were thoroughly painted.

In April, at Great Falls, the fences around the Government lands were lime-washed, and the painting of the iron-work of the gate-house was continued. Between Cabin John Bridge and the receiving-reservoir stones were broken for the repairs of the concrete foundation of culvert No. 8. At the distributing-reservoir the fences, the pipe-vault, and the interior of the gate-houses were lime-washed. In Georgetown the wooden fences at the high-service reservoir, and the gallery under the reservoir, were lime-washed.

At the Washington Aqueduct office the sills of the building were underpinned, and foundations were excavated preparatory to building brick walls under the entire building; it had been ascertained that the wooden posts that supported the building were much decayed.

The stop-cocks on the United States mains, from the distributing-reservoir to the Navy-Yard, were cleaned and oiled, and the large vaults were lime-washed.

In May the painting of the gate-house roof and cornice at Great Falls was finished. The embankments over the conduit at culverts Nos. 2 and 3 were repaired and widened, and the bottom of culvert No. 8 was repaired with hydraulic concrete.

At culvert No. 13 the embankment was repaired and partly widened. At Cabin John Bridge the cut-stone parapets and coping were partially repointed with cement-mortar. In the tunnel leading to a waste-weir in tunnel No. 4 the wooden beams that supported the foot-way were removed and iron beams were set in their place.

The culverts along the aqueduct were examined and the channels of the streams were cleaned out. The embankment over culvert No. 23 was repaired and partly widened. At the distributing-reservoir the lime-washing of the fences and gate-houses was finished and the roadway over the pipe-line was repaired. In Georgetown, at the high-service reservoir, the lime-washing of the fences and gallery was finished. Brick walls were built under the sills of the aqueduct office, and the down-spouts, water and drain-pipes were repaired. The old wooden stairs leading from the street to the grounds below were removed and new ones built in their place.

In June, at Great Falls, the Potomac was shut off from the aqueduct, and the feeder to the aqueduct extending from the Potomac dam to the gate-house was thoroughly cleaned.

The repairing and widening of the embankment over culvert No. 13 was finished. At Cabin John Bridge the repointing of the cut-stone parapets and coping was finished, and the coping, where necessary, was reset. The cut-stone parapets and coping of Griffith Park Bridge were also repointed and the coping reset.

At the receiving-reservoir the telegraph-line was repaired and new poles set. The ditches along the conduit road were cleaned out, and several washes, made in the new embankments by the rain, were refilled.

At tunnel No. 4 the old foot-way leading to the waste-weir was removed and a new one was built in its place.

At the distributing-reservoir repairs were made to the embankments where they had been washed by the rain. At Foundry Branch the overfall over the pipe-line was repaired with stone.

In Georgetown, in the basement of the aqueduct office, the floors were paved with red bricks, the walls were lime-washed, and the doors and windows were painted.

On June 25 the conduit was shut off from the distributing-reservoir, and remained off for 24 consecutive hours. The elevation of the water-surface of the reservoir was recorded each hour, and the quantity of water drawn from the reservoir during the 24 hours was as follows:

	Gallons.
June 25, from 6 a. m. to 6 p. m	12,148,253
June 25 and June 26, from 6 p. m. to 6 a. m	11,104,679
Total quantity	23,252,932

Last year the quantity consumed from 12 m., June 23, to 12 m., June 24, was 24,177,797 gallons.

Each month during the year the outlets on the United States mains were opened, the mains flushed, and the general distribution of Po-

tomac water in the conduits, reservoirs, and pipes was properly attended to.

Since taking charge of this work means have been devised for comparing and recording the clearness of the water at Great Falls, the receiving and the distributing reservoirs. The observations are taken each day, and furnish data to guide in the management of the flow of the water into the reservoirs and mains, and will be of service in future studies looking to the filtration or clarification of the water during the muddy stages of the Potomac.

The estimates for which appropriations should be made for the next fiscal year are as follows:

For engineering, maintenance, and general repairs	$20,000 00
For commencing the construction of the dam at Great Falls across the Virginia channel of the Potomac	50,000 00
For improving grounds around gate-keeper's dwelling at the receiving-reservoir	1,000 00
For building wooden fence around the Government land at the receiving-reservoir	7,000 00
For soiling, sodding, and seeding the embankment and excavation slopes of the distributing-reservoir	15,000 00
For building a wrought-iron truss-bridge over the waste-channel at the receiving-reservoir	11,000 00
For building an over-fall over the connecting-conduit for the waste-channel of the receiving-reservoir	2,000 00
For continuing the macadamizing of the conduit road	10,000 00
Total	116,000 00

The following is a financial statement for the fiscal year ending June 30, 1877:

TITLES OF APPROPRIATIONS.

Act of March 3, 1875.

For building iron truss-roof on gate-house at Great Falls:	
Available July 1, 1876	$2,947 50
Expended in 1876 and 1877	2,947 50

Act of July 31, 1876.

Repairs of Georgetown reservoir:	
Available July 31, 1876	4,000 00
Expended in 1876 and 1877	4,000 00
Engineering, maintenance, and repairs:	
Available July 31, 1876	18,000 00
Expended in 1876 and 1877	18,000 00

The aqueduct generally is in good condition. The cut-stone dam across the Maryland channel of the Potomac received no damage during the spring freshets, except that a portion of the ripraps of the backing was carried over the dam. The water has been too high thus far to replace them, but they can be replaced in July or August, when the water generally falls below the crest of the dam.

This structure is the only one on the Washington Aqueduct remaining unfinished. It should be built entirely across the river to the Virginia shore. The consumption of Potomac water for several years past has amounted to more than the minimum flow of the Maryland channel, and is now very nearly the maximum quantity that can be supplied by the present iron mains. Before the supply can be increased during the summer months it will be necessary to finish the Potomac dam and to lay additional mains from the distributing-reservoir into Washington.

The conduit-road is in good order. It is macadamized from the distributing-reservoir to culvert No. 6. The remainder of the road should also be macadamized.

The slopes of the embankments and excavations should be protected with sods or soiled and seeded with grass. In their present condition every rain-storm damages them more or less.

The Government lands at the receiving-reservoir should be inclosed with a substantial wooden fence. The grounds surrounding the gatekeeper's dwelling should be improved by grading and tree-planting. Powder Mill Branch, which empties into the receiving-reservoir, is liable to sudden freshets; at times the waters have risen beyond the control of the gatekeeper, and caused considerable damage by overflowing the conduit at the waste-channel and waste-weir No. 3. A stone over-fall should be built over the connecting conduit, across the waste-channel, for the passage of the storm-waters.

The wooden bridge over the waste-channel was built in 1863. Its timbers are old and decayed; it should be removed, and a wrought-iron truss-bridge should be erected in its place.

The embankment-slopes of the distributing-reservoir should be sodded, to protect them from the rain. The slopes of the embankments over the pipe-line should also be sodded.

Very respectfully, your obedient servant,

THOS. LINCOLN CASEY,
Lieutenant-Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

K K 4.

ROCK-CREEK BRIDGE OF THE WASHINGTON AQUEDUCT, DISTRICT OF COLUMBIA.

WAR DEPARTMENT,
QUARTERMASTER-GENERAL'S OFFICE,
Washington, D. C., January 9, 1877.

SIR: I have the honor to inclose a copy of a letter which I have thought it proper to send to chairmen of some committees of Congress.

The criticism upon the Rock-Creek bridge, involved in the recommendation some years since to remove the street-railroad traffic from it, and in the recommendation lately made to Congress to cover it over with a wrought-iron truss, on the plea of danger to the 48-inch pipes, affects the reputation of the engineer and of the corps to which he belonged when the work was constructed too much to permit a longer silence on the subject.

There are few iron bridges, I believe, in existence in which the co-efficients of safety against the strains caused by the traffic to which they are exposed are so large.

Very respectfully, your obedient servant,

M. C. MEIGS,
Quartermaster-General, Bvt. Brig. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

LETTER FROM BRIGADIER-GENERAL M. C. MEIGS TO THE CHAIRMAN OF THE COMMITTEE ON THE DISTRICT OF COLUMBIA, UNITED STATES SENATE.

WAR DEPARTMENT,
QUARTERMASTER-GENERAL'S OFFICE,
Washington, D. C., December 29, 1876.

SIR: I notice in the Book of Estimates for the next fiscal year, at page 140, an estimate of $70,000 for building a wrought-iron truss-bridge for the protection of the aqueduct-mains over Rock Creek.

I designed and built the iron bridge at Rock Creek by which the Washington-aqueduct mains enter this city.

The bridge has been much admired. Its elevation and plans have been published in the scientific and engineering journals of England, France, and I think also of Germany.

The centennial commissioners voted to me their diploma and medal for the plans of this bridge and of the stone bridge over Cabin John Run, also on the Washington aqueduct, and I should very much regret to see either of them defaced or covered over.

Both bridges are unique among engineering structures; the Cabin John Bridge being the widest stone arch in existence, 220 feet span, and the Rock Creek Bridge being the only one in which the arched ribs are utilized to convey the water-supply of a city, and at the same time to support a roadway.

I made careful studies for these bridges, and I am confident that it would be perfectly safe to use the Rock Creek iron bridge as a railroad-bridge for the heaviest traffic.

Hence I was surprised and somewhat grieved at seeing a law passed two or three years since to remove the street-railroad track from it on the plea of danger to the mains.

I should still more regret to see it covered over and disfigured by any structure on the plea of protecting the mains. These mains have actually conveyed water and supported a street and railroad—Pennsylvania avenue—and its traffic, according to the original design, for some sixteen years. I watched it carefully for some time after I first admitted to it water and the traffic of the street, and I frequently pass it even now.

So long as I had charge of the bridge it never leaked one drop of water, and I have never, since I relinquished the control of it, seen the evidence in passing of the slightest leak.

Some pieces of the light cast-iron laurel-wreaths, designed to cover over the flange-joints, merely as decorations, have from time to time fallen from the ribs, in consequence of the jarring loose of the screws by which they were attached, or perhaps by their rusting off. But these could be easily replaced at insignificant cost, and their actual removal would not weaken the bridge or injure it, except in its architectural appearance. To cover over and conceal the bridge, which is now an ornament to the city, seems to me to be a useless act of barbarism, and a clear waste of the $70,000 asked for the purpose, a sum probably nearly equal to the original cost of the bridge itself, or of its iron-work.

I hope that no such project will be favorably entertained by your committee, unless, greatly to my surprise, on a strict scientific investigation, a necessity for such a structure shall be clearly proven to exist.

If it has not been needed during the past sixteen years, I cannot conceive that the times now so differ as to make it now necessary.

I am confident myself that a train of heavy locomotives could be safely

run daily and hourly over the bridge, so far as the strength and safety of the aqueduct-mains are concerned.

I remain, very respectfully, your obedient servant,

M. C. MEIGS,
Quartermaster-General U. S. A.,
Formerly Chief Engineer and Constructor of the Washington Aqueduct.

Hon. GEORGE E. SPENCER,
Chairman Committee on the District of Columbia,
United States Senate.

REPORT OF COLONEL O. E. BABCOCK, CORPS OF ENGINEERS.

OFFICE OF WASHINGTON AQUEDUCT,
Washington, D. C., January 22, 1877.

SIR: I have the honor to acknowledge the receipt of a letter, addressed by General M. C. Meigs to the Chief of Engineers, dated January 9, 1877, inclosing a copy of a letter addressed by him to the Chairmen of the Committees on the District of Columbia, and dated December 29, 1876, relative to the Washington Aqueduct iron bridge over Rock Creek, and to the stone bridge over Cabin John Run, referred to me on 16th instant for report.

In reply, I respectfully submit the following: A perusal of General Meigs's letters gives but few points on which to differ or report, and indicates that he believes that the Rock Creek Bridge, which was built nearly twenty years ago, is the best that could be devised for the purpose, and that any alteration made in it would be "a useless act of barbarism" and clear waste of money.

He states that the criticism upon the Rock Creek bridge involved in the recommendation some years since to remove the street-railroad traffic from it, and in the recommendation lately made to Congress to cover it with a wrought-iron truss, on the plea of danger to the 48-inch pipes, affects the reputation of the engineer and of the corps to which he belonged when the work was constructed too much to permit a longer silence on the subject.

That the bridge has been much admired; its elevation and plans have been published in the scientific and engineering journals of England, France, and Germany.

That the Centennial Commissioners voted to him their diploma and medal for the plans of this bridge and of the stone bridge over Cabin John Run, also on the Washington Aqueduct, and that he should very much regret to see either of them defaced or covered over.

That both bridges are unique among engineering structures, the Cabin John Bridge being the widest stone arch in existence, 220 feet span, and the Rock Creek Bridge being the only one in which the arched ribs are utilized to convey the water supply for a city and at the same time to support a roadway.

That he made careful studies of these bridges, and is confident that it would be perfectly safe to use the Rock Creek Bridge as a railroad-bridge for the heaviest traffic.

That he was surprised and somewhat grieved at seeing a law passed two or three years ago to remove the street-railroad track from it, and should still more regret to see it covered over and disfigured by any structure on the plea of protecting the mains.

That some pieces of the light cast-iron laurel-wreaths, designed to

cover over the flange-joints, have from time to time fallen from the ribs in consequence of the jarring loose of the screws by which they were attached, &c.

In reference to the iron bridge over Rock Creek, it will be seen by referring to my annual report of operations upon the Washington Aqueduct dated October 13, 1873, that I stated as follows:

There seems to be no authority of law for the use of this bridge for common travel, although it was tolerated during the late war on account of the demand for passageway upon all the avenues and streets. The constant jarring to which it is subjected has caused many of the ornamental scrolls which encircle the joints of the mains to become loose and drop, and I have no doubt its continued use for a general thoroughfare will eventually destroy its usefulness for aqueduct purposes.

At my request it was examined in 1875 by the House Committee on Appropriations, who saw the effect that the passage of heavily-loaded wagons had produced upon it, and they procured the passage of an act of Congress, in pursuance of which the tracks of the Washington and Georgetown Railroad were removed therefrom, and the travel over it was restricted to light loads.

After the passage of the act above mentioned the bridge was thoroughly repaired and painted, and the castings which had fallen from it were replaced in position. These castings, which General Meigs states are light cast-iron laurel-wreaths, and which can be replaced at insignificant cost, weigh about 100 pounds each.

In 1875, when the committee examined this bridge, forty-two of these casting were on the ground under the bridge, and twelve were in the bottom of Rock Creek, six of which were recovered and six could not be found. The cost of replacing them, including the purchase of six new ones, was $268.15. General Meigs, in admitting the jarring loose of these scrolls, fully justifies my recommendation.

In my annual report upon the Washington Aqueduct dated June 30, 1876, I stated that the entire supply of Potomac water depended upon the preservation of this bridge, and I recommended that the roadway and sidewalks which are now supported by its arches be removed, and that a wrought-iron truss-bridge, with wrought-iron floor-beams and stringers to support the roadway and sidewalks, be erected over the present structure; that a plan had been made for this proposed improvement, and that the estimated cost is $70,000.

This bridge, situated at the west end of Pennsylvania avenue, connecting Washington with Georgetown, reduces the broad roadway of that avenue to a narrow passage 17 feet wide and about 300 feet long. The advantages which would result from the improvement recommended by me, and which are stated in the report above mentioned, are as follows:

First, (and the most important.) The two cast-iron mains, each 4 feet in diameter, and which form the arches of the present structure, would be protected from the jarring caused by passing loads, and all danger of leaking thereby would be avoided.

Second. The roadway, which is now only 17 feet wide, would be 30 feet, and the sidewalks, which are only 4½ feet wide, would be 9 feet.

In regard to the strength of the present structure, I have no doubt of its ability to support the weight of any load likely to come upon it; but, in my opinion, there is danger that such loads will eventually cause its joints to leak.

General Meigs admits that there has been sufficient vibration or jarring to throw down the ornamental scrolls, on which no strains come. In my opinion the amount of jarring or vibration thus admitted must, if continued, destroy in time its usefulness for aqueduct purposes.

As General Meigs has never seen the plan which I have recommended the fact that the Centennial Commissioners voted him a diploma and medal, together with the fact that plans of his bridges have been published in scientific and engineering journals in England, France, and Germany, does not give him the right to intimate that the improvement I have recommended is calculated to deface or conceal either Cabin John Bridge or Rock Creek Bridge.

General Meigs's plans have, it is true, been published in English and French scientific journals, but notwithstanding the great progress made in hydraulic engineering, and the vast sums expended since the construction of the Washington Aqueduct, I have yet to hear of his plans and designs for bridges being adopted on any work.

M. Huet, *ingénieur des Ponts et Chaussées*, in a description of the Croton and Washington Aqueducts, published in the "*Annales des Ponts et Chaussées*," remarks that the tubes of Rock Creek Bridge are covered inside with a lining of wood 3 inches in thickness, for the purpose of diminishing vibration, and that notwithstanding that precaution it will be difficult for that bridge to constantly perform its duty without too many leaks or accidents, ("*sans trop de fuites ni d'accidents.*")

With reference to Cabin John Bridge, no appropriation is asked for work on it. Since it has been under my charge, cut-stone parapets have been constructed to protect the public, and an asphalt pavement to protect the masonry. The only act of barbarism that I know of was the defacing of the abutments by changing the inscriptions.

Plans and descriptions of it have been published in England and France; the latest I have seen is that entitled "*Travaux Publics des États-Unis d'Amérique en* 1870*; rapport de mission par M. Malezieux, professeur à l'École Nationale des Ponts et Chaussées.*"

In his description of the Washington Aqueduct, M. Malézieux does not concede the credit of designing Cabin John entirely to General Meigs, but he says "that the studies of all its details were made, and it was constructed by, Alfred L. Rives, a graduate of the *École des Ponts et Chaussées.*"

As to the reflections upon the Corps of Engineers, General Meigs assumes that because he was employed upon the Washington Aqueduct, when a member of the corps, sixteen years ago, he has the right, without inquiry, to write a protest to committees of Congress, pronouncing the recommendation of an engineer officer, submitted through his chief and the Secretary of War, as "barbarous and a waste of money." Does not such an assumption seriously reflect upon the officer making such recommendation, and is it not a direct violation of that courtesy that should exist between different branches of the service?

I wish it to be distinctly understood that, as the engineer in charge of the Washington Aqueduct for the last five years, my observation convinces me that if those pipes are not protected the constant jarring will eventually injure them and impair their usefulness for conducting Potomac water into the city, though the removal of the railroad-tracks and the restriction of the travel to light loads relieves them in a great measure.

The construction of the Washington Aqueduct was begun A. D. 1853. The principal changes that have been made from the original plans of General Meigs may be briefly mentioned as follows, namely:

The substitution at Great Falls of a cut-stone dam for an embankment of loose stones.

The building of cut-stone parapets on Cabin John Bridge and on Griffith Park Bridge.

The building of the connecting conduit at the receiving-reservoir.

The widening and raising of the embankments over the conduit between Great Falls and the distributing-reservoir.

The lining of the water-slopes of the distributing-reservoir dams with slope wall from 18 to 24 inches in thickness.

The fencing of reservoirs; the laying of a cast-iron main, 3 feet in diameter, from the distributing-reservoir to Capitol Hill.

The improvement made at the high-service reservoir in Georgetown by the substitution of an ornamental cornice of cast iron for an unsightly brick dome.

Although the official connection of General Meigs with the Washington Aqueduct ceased in 1861, each of these changes met with strenuous opposition from him. They, however, received the approval of Congress, and have been either wholly or partially completed.

With regard to the necessity of laying an additional main from the distributing-reservoir into Washington, General Meigs stated under oath, before the House Committee of the District of Columbia, on April 27, 1870, as follows:

> The supply now, as it comes into the city, is sufficient for a population of five hundred thousand. The supply of water would be improved by filling the reservoir up to the proper height, which the gentlemen who have charge of the work seem to be afraid to do. But I will warrant it will stand, and this will give an additional height of 10 feet, which would supply many more of the higher stories with water. (See Mis. Doc. No. 132, Forty-first Congress, second session, p. 42.)

To have raised the flow-line of the distributing-reservoir 10 feet higher than it was in April, 1870, if such a thing could have been done, would have brought it several feet above the top of the reservoir-dams, (which are higher than the fountain-head at Great Falls,) and flooded the surrounding country, which would certainly have been an "act of barbarism."

Since then the "36-inch main" has been laid; the consumption of Potomac water has more than doubled; an additional supply of water is again demanded, and to meet this demand General Meigs has recently advocated, through the press, the building of a tunnel, 5 miles long and 10 feet in diameter, from the distributing-reservoir to the high grounds north of Washington, and the building there of a second distributing-reservoir.

It may be proper to add in this connection the following, taken from a report upon the Washington Aqueduct, by Silas Seymour, Esq., an eminent civil engineer, and formerly chief engineer of the Washington Aqueduct:

> The plans designed by General Meigs for the Washington Aqueduct were probably the best that could be devised at the time from the lights and experiences then available for reference.
>
> The changes which have been made therefrom and adopted should be regarded as only the natural results of experience and observation on the Washington Aqueduct and other works of a similar nature during a period of several years which have elapsed since the commencement of the work, and should, therefore, not be regarded as reflecting any discredit upon the original plans.
>
> The history of this work would differ materially from that of any other public improvement in the country if the experiences and observation of each succeeding year of its construction and use did not develop the expediency of some changes in the original plans, which, if adopted, would prove advantageous to the work.

General Meigs's letters are returned herewith, and I also transmit a plan showing two designs for the bridge I have recommended, and which I request may be returned to this office.

Very respectfully, your obedient servant,

O. E. BABCOCK,
Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

REPORT OF BOARD OF ENGINEERS.

ARMY BUILDING,
New York, April 7, 1877.

GENERAL: The Board of Engineers constituted by Special Orders No. 8, February 2, 1877, Headquarters Corps of Engineers, to examine into the propriety of certain modifications of the Rock Creek Bridge, Washington Aqueduct, projected by the engineer officer in charge, met in Washington February 7. Having examined drawings of the bridge and the structure itself, and discussed the question submitted to them, they adjourned February 9, to meet again in New York City. Thence they submitted to the Chief of Engineers a preliminary report, dated February 17, giving a general opinion as to the effects of loads upon the present bridge in connection with its strength, stability, and safety, without, however, deciding the propriety of the structure proposed by the engineer in charge to provide a wider roadway across Rock Creek, concluding to report more fully upon all these points in a future communication.

That report they now have the honor to submit, as follows:

The superstructure of the Rock Creek Bridge rests essentially upon two iron pipes that convey all the water from the distributing-reservoir into Washington that is required in that city. These pipes are 4 feet interior and 4 feet 3 inches exterior diameter. The span of this bridge is 200 feet, the rise 20 feet. There are in each of these arches 17 sections of pipe which abut together, and are further secured by flanges strongly riveted. Iron trusses over the haunches, that is starting from the springing lines and extending nearly to the crown of the arches, are fastened to the iron pipes and receive the roadway. By this construction the bridge is much stiffened.

These ribs are strong, and it will appear that without the trusses they can bear in safety the heaviest uniformly-distributed load to which they will probably ever be subjected.

Accompanying sketch A will illustrate the following discussion of the question of loads, resulting thrusts, and corresponding pressures upon the iron of the tubes:

The weight of the Rock Creek Bridge not loaded, as given by General Meigs, is	1,023,495 pounds.
Number of square feet of roadway surface of bridge is 200′ by 26′, = 5,200 square feet. Allowing 100 pounds per square foot for load of men, which is excessive, gives for weight of such load	520,000 pounds.
And for total weight of bridge thus loaded	1,543,495 pounds.

It is probably judicious to allow 100 pounds per foot for a crowd upon the bridge; not because it could by any possibility be dense enough to produce that weight, but for the reason that by its motion the effect of a greater weight is produced.

Taking the weight of the bridge loaded, therefore, at 1,543,495 pounds, the thrust may be thus obtained:

Referring to Figure 1, it is apparent that there will be a tendency of each half arch of the bridge to rotate about R′. But as the chords from R′ to R are longer than from R′ to C the pressure will be greater at R than at C. So at the springing-line joint the pressure will be greater at R′ than at C′. As the joints cannot open at C or C′ unless the abutments give way, the most unfavorable supposition that we are free to make is that the strain may possibly be reduced to 0 at those points. This would result in twice the pressure at R and R′ of the average on

the joint, provided the pressure is uniformly increasing from C to R and from C′ to R′. The point of application in that case of the thrust due to each half arch tending to rotate will be at P; R P being $\frac{1}{3}$ of R C, and the resultant of pressures on springing-line joints will be at P′, $\frac{1}{3}$ distant from R′ to C′. The thrust at P is due to the half arch rotating about P′. Hence—

$$\text{Thrust } T = \frac{\frac{1}{4} \text{ weight of bridge} \times BP'}{AP'} = \frac{771748 \text{ lbs.} \times 50\frac{1}{4} \text{ ft.}}{21\frac{1}{4}}$$

which gives, T = 1,812,710 pounds; and thrust on each rib is $\frac{1}{2}$ of T, or 906,355 pounds. Area of cross-section of pipe is 233$\frac{1}{4}$ inches. Average pressure on square inch, therefore, at crown joint would be = 3,886 pounds.

This would give approximately 7,772 pounds* pressure at R.

The resultant at P′ will be due to thrust at P, 906,355 pounds, and $\frac{1}{4}$ weight of bridge = $\sqrt{906355^2 + 385870^2}$ = 985,078 pounds. Dividing by 233$\frac{1}{4}$ inches gives average pressure per square inch = 4,223 pounds, and real pressure at R′ twice that amount, or 8,446 pounds per square inch. This seems to be the greatest pressure to which any portion of the iron at the joints of the pipes can be submitted by the largest uniformly-distributed load that can be put upon the bridge. This weight per square inch is from $\frac{1}{10}$ to $\frac{1}{12}$ of the rupturing weight by pressure of cast iron. There is no risk, therefore, of the bridge being injured by any dead load, uniformly distributed, that may be thrown upon it.

The following analysis will serve to show the effect of an unequal distribution of weights upon the bridge:

	Pounds.
Bridge's weight as before is	1,023,495
Weight over each half rib	255,876

Let us suppose a weight of 20 tons thrown upon one-half of the bridge from N to O, Fig. 2, equally distributed, or producing its effect at (M) the middle of the half arch.

On the right half of each rib the additional weight is 20,000 pounds, making the whole weight on the right half of each rib 275,876 pounds; on left half of each rib the weight remaining is 255,876 pounds.

Now, in order that these weights may counterbalance each other, the points of resultant pressures on springing-line joints must be different. The right arch being heavier than the left, will tend to rotate upwards. The action of the first raises its resultant point of thrust above the center of joint; that of the second depresses it below center. It will probably be safe, therefore, to assume the resultant points of application of the two thrusts at center, P, of crown joint, (Fig. 2,)† and P′ as in preceding discussion, $\frac{1}{3}$ distant from R′ to C′. AP′ then becomes 20$\frac{3}{4}$ feet and BP′ = 50$\frac{1}{2}$ feet, and thrust of right half arch becomes

$$\frac{275,876}{20\frac{3}{4}} \times 50\tfrac{1}{2} = 671409.$$

$$\text{Thrust of left half arch} = \frac{255,876}{A'P''} \times B'P''.$$

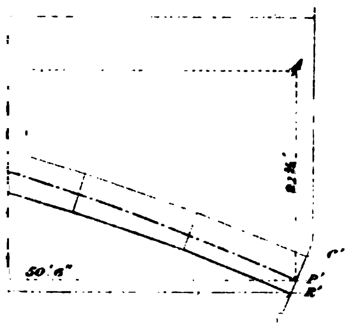
The equilibrium of the arch requires that these thrusts should be equal or

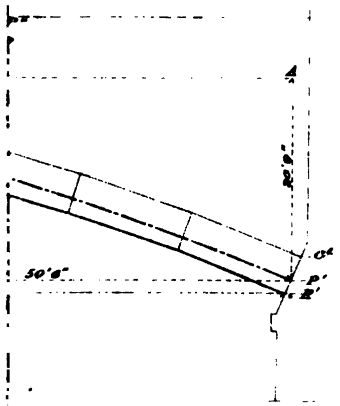
$$\frac{A'P''}{B'P''} = \frac{255876}{671409}.$$

A′ P″ and B′ P″ are each only known approximately, but by assum-

* Under the supposition that pressure is zero at C.

† If assumed at P, as in Figure 1, the resulting point of application P″ will not be materially changed.

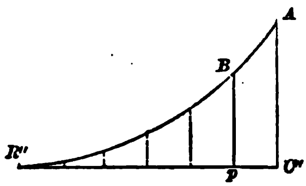

50'6"
C'
P'
R'


A
50'6"
P'
R'

ing B′ P″ and solving the equation by successive corrections, we shall find B′ P″=51 and A′ P″=19.44. Constructing position of P″ geometrically from above value of A′ P″, or more accurately determining its position from calculation, we find it $\frac{1}{3}$ distant from C″ to R″. This, therefore, is the point of resultant thrust on joint C″ R″. The thrust of right half arch, therefore, tending to revolve about P′, is exactly equal to thrust of left half arch tending to revolve about P″. Equilibrium is the result, with no greater pressure on outer edge of joint C″ R″ than on inner edge of joint C′ R′, which is double the average pressure per square inch, if pressure were distributed over the whole joint.

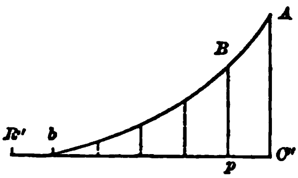
This last discussion shows that point of application P″ will rise on the joint as the extra weight at M is increased. Forty thousand pounds are assumed to be as great an excess of weight on one half arch above the other as will ever occur. A crowd passing over the bridge might possibly be dense enough as it left to throw an excess one-half greater than that assumed above. Under that supposition the resultant will pass through p, about $\frac{1}{6}$ distant from C″ to R″.

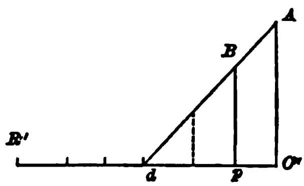
It is impossible to determine with any precision how this pressure will be distributed over joint R″ C″ so as to give resultant at p, $\frac{1}{6}$ distant from C″. That will depend upon the manner of yielding or compression of substance of joint and of the iron itself. The pressures along the line of the joint may be ordinates of a curve thus:



So that the moment of surface p BAC″ with reference to p B will be equal to that of surface R″ p B.

Or the distribution may be th





The pressures being represented by ordinates to an intermediate curve Ab, or to the right line A d. The distribution cannot be determined as the result of any law, but will depend, as before stated, upon the manner of compression of the substance of the joint or condensation of the iron itself. The greatest resultant pressure, however, at C″ will not probably exeeed four times that of the average, if pressures are distributed equally over whole joint. The resultant pressure on joint in this case is found to be, if equally distributed, 3,215 pounds per square inch, so that the pressure at C″ under above supposition would be 12,860 pounds, or $\frac{1}{8}$ of ultimate strength of cast iron. Accompanying drawings show the three curves of pressure corresponding to the foregoing supposed distribution of weights upon the bridge. These curves of pressure lie well within the extrados, and exhibit conditions favorable to the stability. It would seem, therefore, that were the bridge formed of the

two arched ribs only, equilibrium would result therefrom, and that the structure would be safe under the greatest uniformly-distributed load that would come upon it, and under any loads that would probably pass over the bridge, changing from one position to another.

In fact, the trusses ought not to be taken into account in estimating the stability or safety of the bridge, as they do not materially reduce the thrust on the cast-iron pipes. They might prevent a change of form sufficient to cause the bridge to fall, but could not prevent those increased pressures on the inner and outer edges of the joints which have been investigated in the foregoing discussion.

It is difficult to say what will be the ultimate effect of the constant jarring of the bridge. Vibratory motion injures wrought-iron, by making it more crystalline, thereby diminishing its tensile strength; but we do not know that it injures the strength of cast-iron to resist pressure. We can conceive that vibration through sensible arcs might produce an effect somewhat similar to an impulse or blow, and in that way increase the pressure very largely; but this bridge seems to be too stiff to admit of such large vibrations.

It has been found by experiments upon railroad-iron used as a bridge that high velocities increase the deflection of the iron many fold as compared with low velocities, and that one half of the statical breaking weight, when moved rapidly, resulted in breaking the bars. In that trial the weights came immediately on the bars and the motion was very rapid. Teams pass no faster than a walk on the Rock Creek bridge, and their weights are transmitted through a superstructure of such stiffness, that the effect of the motion is diffused, and loses the character of an impulse or blow before reaching the iron pipes. We conclude, therefore, that the bridge has a superabundance of strength, as it ought to have, since the water-supply of the city of Washington is dependent upon the safety of this structure.

Should it be necessary to widen this bridge, there is no doubt that the proposition of the engineer in charge to put a truss beneath the roadway will accomplish the end in view cheaply, as it will avoid widening the abutments. The truss above the roadway will be unsightly in such a position. In fact, the undergrade truss will be objectionable on the same ground, so far as it is exposed to view.

It would, in our opinion, therefore, better accord with the position on Pennsylvania avenue and with the general character and architectural effect of other aqueduct structures to widen this structure, without changing its design, by the addition of two arched iron ribs similar to those of the present bridge and by widening the abutments.

These two arched ribs should be made about as heavy as those of the present bridge. As the previous discussion shows the latter to be abundantly strong without the truss-work, in the new construction the greater portion of the whole weight of the bridge could be thrown upon the added arches, not used as water-pipes.

We regard the arch as far more sightly, beautiful, and architectural than the truss, and therefore more suitable for this position.

Respectfully submitted.

Z. B. TOWER,
Colonel of Engineers, Bvt. Maj. Gen., U. S. A.
H. G. WRIGHT,
Lieut. Col. of Engineers, Bvt. Maj. Gen.
Q. A. GILLMORE,
Lieut. Col. of Engineers, Bvt. Maj. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORT OF LIEUTENANT-COLONEL THOMAS LINCOLN CASEY, CORPS OF ENGINEERS.

OFFICE OF THE WASHINGTON AQUEDUCT,
Georgetown, D. C., July 19, 1877.

GENERAL: I have the honor to acknowledge the receipt of your letter, dated April 26, inclosing for my information copies of certain papers relating to the Washington Aqueduct Bridge over Rock Creek, requesting me, at my convenience, to fully investigate the question attending the present and prospective use of that bridge as a highway, and to report my views as to whether, in view of the restrictions authorized by act of Congress to be placed upon the travel over the bridge, the interests of the United States or of the citizens of Washington and Georgetown seem to demand any increase of the width of the roadway and of the footway of the bridge.

In reply, I respectfully submit the following:

The superstructure of the Rock Creek Bridge was constructed upon two cast-iron arch-shaped mains, 48 inches in diameter, which rest upon stone abutments on either side of the creek, and are used for the purpose of conveying the water from the Washington Aqueduct over Rock Creek into the city of Washington.

By an act of Congress approved May 17, 1862, the Washington and Georgetown Railway Company was created, and authorized to construct and lay down a double-track railway in the cities of Washington and Georgetown, through and along the following avenues and streets:

Commencing on Bridge street at the intersection of High street; thence along said Bridge street to its intersection with the street running to the tubular bridge over Rock Creek to Pennsylvania avenue, in the city of Washington; along said avenue to Fifteenth street west, &c.

At the time of the passage of this law the embankments at the end of the bridge had not been completed, and the bridge had been used for no other purpose than for the passage of the aqueduct water. The embankments were completed in 1862, and the bridge was immediately used as a general thoroughfare for street-cars and wagons of all descriptions.

The railroad company claimed to have derived its authority for the use of this bridge from that portion of the law above quoted, and while there seemed to be no authority of law for the use of this bridge for common travel, it was permitted to be so used during the late war on account of the demand for passage-way upon nearly all the public avenues and streets, and it continued to be used for such purposes until after the passage of an act of Congress, approved March 3, 1875, of which the following is an extract:

* * * * *And provided further*, That the Chief Engineer is hereby directed to notify the Washington and Georgetown Railway Company to remove their railway-track from the Washington Aqueduct Bridge over Rock Creek within one year from date of said notice, and said company shall make such removal within the year aforesaid. * * And said Chief Engineer may establish and publish regulations prohibiting the passage of heavily-loaded wagons and carriages over said bridge. * * * *

A copy of this law was sent to the president and directors of the Washington and Georgetown Railway Company, and they were notified to remove their tracks from the bridge within one year from the date of said notice.

In the following October they removed their rails, and since then the passage over it of heavily-loaded wagons and carriages has been prohibited.

Even with this restriction upon the travel, the bridge is often thronged with vehicles, and as it is the most direct line of communication between Washington and Georgetown I am of opinion that in the future the travel over it will increase. The restrictions that have been placed upon the travel by act of Congress must be, to a certain extent, detrimental to the interests of the citizens of Washington and Georgetown.

The street-cars and chariots now have to cross Rock Creek by the M street bridge, and reach Pennsylvania avenue by way of Twenty-sixth street west, which is a comparatively narrow street, 80 feet wide, and its grade much steeper than that of Pennsylvania avenue from Rock Creek. Freight of all kinds, including lumber, stone, brick, farm-produce, &c., has to cross Rock Creek by either K, M, or P street bridge. Neither of these routes has as easy grades as those by way of Pennsylvania avenue.

In view of the restrictions authorized by Congress to be placed upon the travel over this bridge, I am of opinion that if they are continued in force the interests of the United States do not at present demand any increase of the width of the roadway and of the footway of the bridge; but I am further of opinion that the present and prospective interests of the citizens of Washington and Georgetown do demand an increase in the width of the roadway and of the footway, the present width being, of the roadway only 17 feet, and of the footways 4½ feet each.

The abundant strength and stiffness of the present bridge, under any statical or moving loads that are likely to be placed upon it, are clearly shown by the investigations of the Board of Engineers, as detailed in its report of April 7, 1877, and I agree with it as to the manner in which the widening of the road and footway should be accomplished, should it be decided to increase their width, namely, by the addition of two arched iron ribs, similar to those of the present bridge, and by widening the abutments. The estimated cost of widening the bridge in the manner above stated is $75,000.

Very respectfully, your obedient servant,

THOS. LINCOLN CASEY,
Lieutenant-Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

APPENDIX L L.

SURVEY OF THE NORTHERN AND NORTHWESTERN LAKES AND THE MISSISSIPPI RIVER.

ANNUAL REPORT OF MAJOR C. B. COMSTOCK, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, Mich., June 1, 1877.

GENERAL: I have the honor to report the progress of the surveys of the northern and northwestern lakes and the Mississippi River, from July 1, 1876, to June 1, 1877.

LAKE ERIE.

At the date of my last report the reconnaissance for the primary triangulation had been carried as far west as Cleveland. During the year this reconnaissance has been extended west to the vicinity of Sandusky by Assistant Engineer G. A. Marr, who again took the field this spring on May 1, and is now extending it to the west end of Lake Erie. The reading of the angles of the primary triangulation was continued by Assistant Engineers Wisner, Flint, Woodward, and Darling, who carried the work from Westfield, N. Y., to the vicinity of Painesville, Ohio, although some of the angles remain to be read.

The topography and inshore hydrography were carried by the parties of Assistant Engineers Lamson, Towar, and Terry from Ashtabula, Ohio, to Vermillion, Ohio, and the offshore hydrography, which was carried on by Lieut. P. M. Price with the steamer Ada, made the same progress.

On account of the late date of the passage of the appropriation bill, parties could not be sent into the field till early in August, 1876, and were withdrawn late in October, or in November. Some of the best part of the season for field-work was thus lost, less progress was made, and the cost was increased.

On May 8 and 10, 1877, the triangulation parties of Assistant Engineers Wisner and Woodward, the shore parties of Assistant Engineers Lamson, Towar, and Terry, and the steamer Ada, commanded by Lieut. D. W. Lockwood, were sent into the field, and are now continuing the work westward from where it closed last fall.

STATE OF MICHIGAN.

The determination of points in aid of State surveys has been continued, latitudes being observed with a zenith-telescope, and longitudes being determined by telegraphic connection with the lake survey observatory at Detroit.

Capt. H. M. Adams observed at Detroit, and Lieutenant Lockwood, in August, 1876, occupied the stations Willow Springs, Ill., Saint Louis and

Saginaw, Mich., observing the magnetic elements also at each of these stations. The stations for the primary triangulation to connect Lakes Michigan and Erie having been erected for a distance of one hundred miles east from the south end of Lake Michigan, Lieut. P. M. Price and Assistant Engineer A. R. Flint took the field, to measure the angles of this triangulation, on May 8, 1877.

MISSISSIPPI RIVER.

Early in November, 1876, Lieuts. D. W. Lockwood and P. M. Price, and Assistant Engineer F. M. Towar, were sent to Cairo to begin a survey of the Mississippi River from Cairo south.

Lieutenant Lockwood was instructed that the objects of the survey were to obtain a good map of the river, to get data for any improvements needed for the purposes of navigation, and to obtain the data needed for the location of levees.

He was instructed to base the topographical surveys on a secondary triangulation, so that the work, when once done, might be the reliable base for all future partial surveys; to leave numerous permanent stone-marks, to which future changes might be referred, these marks being determined, both in position and height; to run continuous lines of levels along one or both banks, and to run level-lines back from the river once in a mile, so as to locate contour lines for each three feet of elevation, with the aid of any intermediate stadia-work. He was also to obtain information as to the character of the bed and banks of the river, and the heights at different points of the highest known floods. Lieutenants Lockwood and Price measured a secondary base-line, and read the angles of the secondary triangulation. Lieutenant Lockwood determined the latitude of a point in Cairo by two nights' work with a zenith-telescope, the azimuth of a triangle-side by six nights' work with a 12-inch theodolite, and, in connection with Captain Adams, at Detroit, determined longitude by two nights' work.

The topographical party under Mr. Towar carried the topography and hydrography of the river from a point five miles above the junction of the Ohio and the Mississippi to a point eight miles above Columbus, Ky.

As the work could only be done well during the low river, which comes in the late fall and winter, and as the winter was very cold, with much ice in the river, the progress was slow; there was, moreover, but little money available for the work.

A line of levels of precision was run from Cairo, Ill., to Columbus, Ky., by Assistant Engineers Lehnartz and L. L. Wheeler.

In previous work the lines have been leveled in duplicate by different observers, with different instruments. To avoid the delay arising from the duplication of the work, I have tried in a part of this line a different method, which seems to furnish all necessary checks on errors.

Two lines of levels are carried on the two sides of the road simultaneously, by one observer, with one instrument. On one side of the road a rod is used, which is numbered from top to bottom; on the other side, the rod used is numbered from bottom to top.

All readings on one side are taken first, and notes of the two lines are kept in separate books.

One leveler makes about two thirds the progress that two would, working in duplicate.

MISCELLANEOUS.

The determination of the heights of the great lakes above mean tide at New York City has been continued. A line of levels has been run

independently, in duplicate, from Escanaba, on Green Bay, to Marquette, on Lake Superior, to determine the difference of elevation of Lakes Michigan and Superior.

The work was of the kind known as levels of precision, the Kern levels and rods being used. The two lines, on reaching Marquette—distant 65 miles from Escanaba—differed by 31.4 millimeters, and the greatest difference between the results of the two lines at any intermediate point was 41.8 millimeters. The elevation of the highest intermediate reference-point above Lake Superior was 190 meters. The resulting height of mean surface of Lake Superior from January 1, 1871, to December 31, 1875, above mean surface of Lake Michigan from January 1, 1860, to December 31, 1875, was 6.249 meters, or 20.50 feet.

To complete this work, there only remained the line from Lake Erie to Lake Huron to be releveled. Assistant Engineers F. W. Lehnartz and L. L. Wheeler have just completed this work. A preliminary reduction gives mean level of Lake Huron 8 35 feet above mean level of Lake Erie, from January 1, 1860, to December 31, 1875.

Neglecting for the present the slight difference of level of Lakes Michigan and Huron, which probably does not exceed one or two tenths of a foot, we have, as a preliminary value correct to the nearest foot, the mean level of Lake Huron 582 feet, and of Lake Superior 602 feet above mean tide at New York.

At the request of Capt. W. S. Stanton, United States Engineers, Capt. H. M. Adams observed here, in connection with Captain Stanton, for telegraphic difference of longitude between Fort Fetterman, Wyoming, and Detroit. At a similar request from Lieut. W. Hoffman, the longitudes of Forts Stockton, Concho, and McKavett, in Texas, were determined; Captain Adams observing at Detroit, and Lieutenant Hoffman at the Texas stations.

The observation of water-levels of the lakes has been continued at Sacket's Harbor and Charlotte, N. Y.; at Erie, Pa., and Cleveland, Ohio; at Detroit, Port Austin, Sault Ste. Marie, and Escanaba, Mich., and at Milwaukee, Wis.

OFFICE-WORK.

During the winter the reduction and plotting of the summer's work on Lake Erie has nearly been completed, giving 21 antiquarian sheets of detailed topography and hydrography.

The plotting of the field-work on the Mississippi River has been begun.

The longitude, latitude, azimuth, and magnetic work at Willow Springs, Ill., Saginaw and Saint Louis, Mich., and Cairo, Ill., has been reduced.

The longitude-work in connection with Fort Fetterman, Wyo., and Forts Stockton, Concho, and McKavett, Tex., has been reduced.

The determination of the constants of the Repsold base apparatus has been begun.

The Clarke yards have been compared with each other at a temperature near 47° F.

The five bases, measured with the Bache-Wurdemann apparatus, have been recomputed, a method being used which estimates the effect of the difference of temperatures of the iron and brass bar in the apparatus.

The levels of precision between Escanaba and Marquette, Mich., have been reduced.

The primary triangulation from the Sandy Creek base at the east end of Lake Ontario to Tonawanda, N. Y., has been adjusted.

During the year Mr. Mueller has nearly completed the chart of La Ontario; scale, $\frac{1}{400000}$.

Mr. Molitor has completed the chart of Detroit River, scale $\frac{1}{400}$ which has been photolithographed.

Mr. Fisher has completed coast-charts Nos. 1 and 3, of Lake Michiga on a scale of $\frac{1}{80000}$. No. 1 extends from Portage to Manitowoc, ar No. 3 embraces the vicinity of Milwaukee. Both have been phot lithographed.

Mr. Witzleben has nearly completed coast-chart No. 1, of Lake Ont rio; scale $\frac{1}{80000}$.

Mr. Wansleben has completed coast-chart No. 2, of Lake Michiga scale $\frac{1}{80000}$, embracing the vicinity of Sheboygan, and has nearly co pleted coast-chart No. 7, of Lake Michigan.

No. 2 has been photolithographed. Mr. Von Hippel has complet coast-chart No. 5, of Lake Michigan, extending from New Buffalo Chicago, on a scale of $\frac{1}{80000}$, and has nearly completed coast-chart 4, Lake Michigan; scale, $\frac{1}{80000}$.

Mr. Franke has completed chart No. 6, Saint Lawrence River, bracing the Thousand Islands, on a scale of $\frac{1}{30000}$, which has b photolithographed. He has also nearly completed coast chart No. Lake Michigan; scale, $\frac{1}{80000}$.

The following table gives a *résumé* of the field-work done betw May 1, 1876, and May 1, 1877:

Surveys of northern and northwestern lakes and Mississippi River.

Longitudes determined telegraphically	
Latitudes determined	
Primary triangulation stations occupied	
Secondary triangulation stations occupied	
Miles of developed shore-line	
Square miles of topography	
Square miles of inshore hydrography	
Antiquarian sheets of topography and inshore hydrography plotted during winter	
Sheets of shore hydrography	
Lines of deep-sea soundings, Lake Erie	
Miles of precise leveling, in duplicate	
Stations occupied for determination of magnetic constants	
Secondary base-line measured	
Secondary azimuth determined	

The standards of length of the lake survey have now been well d mined, and will probably have their values but slightly changed i ture. A description of them and a discussion of their values is ther given in Appendix A. The Keweenaw base having been recomp and its length, in terms, of the 15 feet brass bar in melting ice h been found, a summary of the methods, and results, is given in A dix B.

The results of longitude work by Capt. H. M. Adams are giv Appendix C.

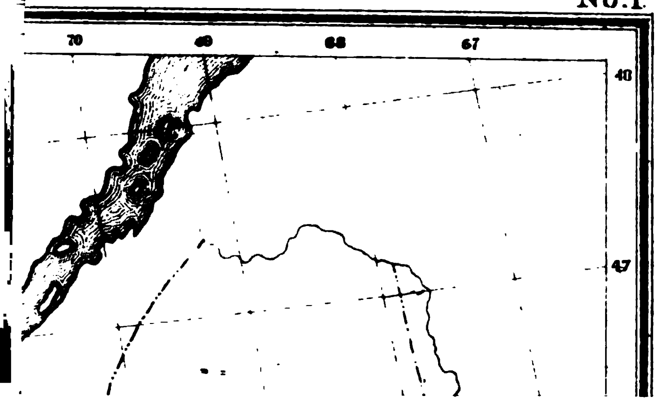
The results of longitude work by Lieut. D. W. Lockwood are in Appendix D.

The results of magnetic work are given by Lieut. C. F. Powell T. N. Bailey in Appendix E.

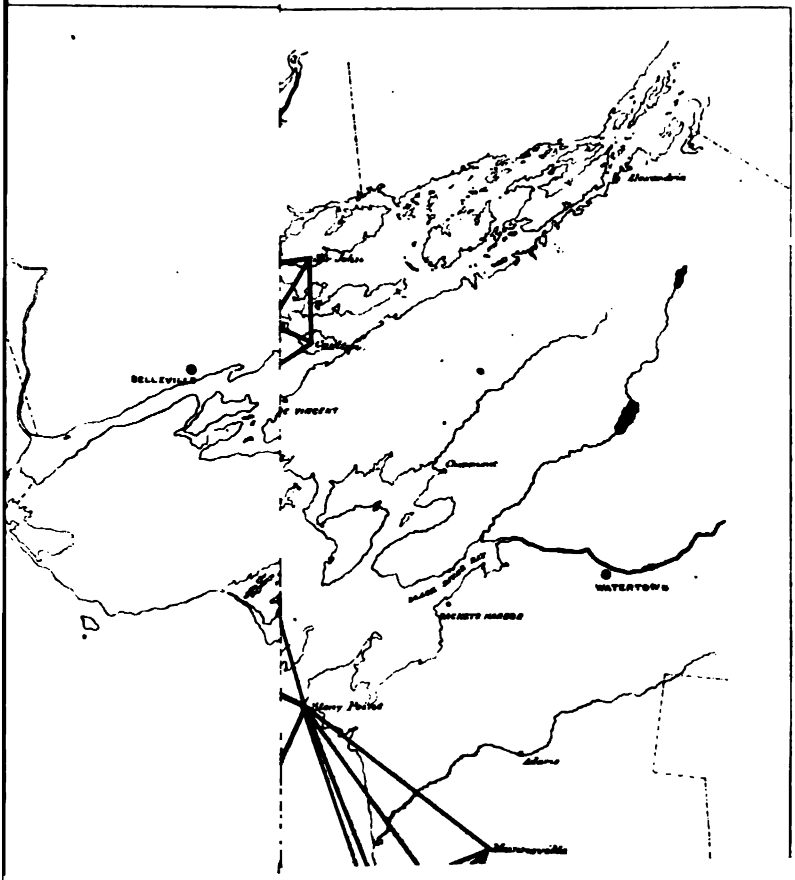
An account of the leveling of precision between Escanaba and quette is given by Assistant Engineers Lehnartz and L. L. Wheel Appendix F.

Results of continuation of water-level observations on the lak given in Appendix G.

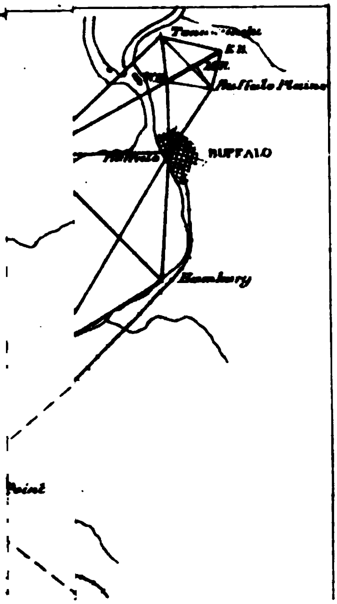
No.1.



Nº 2.



No. 3.



No. 4.

Appendix H gives a list of the published charts of the Lake Survey, the number of charts issued in different years, and a list of tracings furnished to different persons.

Appendix I gives reports of chiefs of parties showing details of work.

Three sketches are forwarded herewith showing the general progress of the Lake Survey, and of the triangulation of Lakes Ontario and Erie.

The following officers have been under my command during the past year: Capt. H. M. Adams, First Lieut. D. W. Lockwood, First Lieut. C. F. Powell, First Lieut. P. M. Price, and Second Lieut. T. N. Bailey. Lieutenant Bailey was relieved from the Lake Survey August 23, 1876.

I am indebted to the officers and assistant engineers of the Lake Survey for hearty co-operation in its work.

Estimate of funds for continuance of survey of northern and northwestern lakes and Mississippi River, for the fiscal year ending June 30, 1879.

For continuing survey of Lake Erie for determination of points in aid of State surveys and construction of maps; for continuation of triangulation south from Chicago and east to Lake Erie; for survey of Mississippi River and miscellaneous	$218,500 00
Details as follows:	
LAKE ONTARIO.	
Construction and engraving of maps	6,000 00
LAKE ERIE.	
Completion of triangulation and measurement of base, three parties	24,000 00
Reduction of work, construction and engraving of maps	10,000 00
LAKE MICHIGAN.	
Continuation of triangulation east from Mungo and south from Chicago; three triangulation parties and publication of maps	30,000 00
MISSISSIPPI RIVER.	
Continuation of the triangulation, six parties	24,000 00
Continuation of topography and hydrography, six parties	51,000 00
Continuation of levels, three parties	10,500 00
Purchase of steam-launches and quarter-boats	18,000 00
Reduction of work, construction and publication of maps	20,000 00
MISCELLANEOUS.	
For water-level observations; quarters and fuel for officers; determinations of points in aid of State surveys; office-rent, fuel, stationery, instruments, and miscellaneous	25,000 00
	218,500 00

Very respectfully, your obedient servant,

C. B. COMSTOCK,
Major of Engineers, Bvt. Brig. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

II.—REPORT OF CAPTAIN H. M. ADAMS, CORPS OF ENGINEERS.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, Mich., June 30, 1877.

GENERAL: I have the honor to report the following progress in the survey of northern and northwestern lakes and the Mississippi River for the months of May and June, 1877.

LAKE ERIE.

The reconnaissance for primary triangulation has been extended from Sandusky, Ohio, to the west end of Lake Erie. The reading of the angles of this triangulation has been continued from Painesville, Ohio, and has been completed as far west as Cleveland, Ohio.

The topography and inshore hydrography has been continued from Vermillion, Ohio, west to Scott's Point, Ohio, including Kelley's Island, Point Pelée Island, the Bass Islands, East Sister Island, and the adjacent reefs and shoals.

The offshore hydrography has been extended west and north from Vermillion, Ohio, to Monroe, Mich., by Lieut. D. W. Lockwood, United States Engineers.

LAKE MICHIGAN AND STATE OF MICHIGAN.

The angles of the primary triangulation connecting Lake Michigan and Lake Erie have been read at stations Michigan City, Bald Tom, and Bertrand.

The measurement of a base-line has been commenced at Summit, Ill.

MISSISSIPPI RIVER.

Lieut. C. F. Powell was sent to Memphis, Tenn., May 30, to make observations for longitude, latitude, and azimuth; to select a site for a base-line, and make a reconnaissance for triangulation south of Memphis.

The longitude work at Memphis, in connection with observations at Detroit by Captain Adams, has been completed. Observations for latitude at Memphis have also been completed.

OFFICE-WORK.

Coast-charts Nos. 4 and 6, Lake Michigan, have been completed.

Number of lake-survey charts issued during the month of June, 1877, 420.

Total for year ending June 30, 1877, 3,156.

Financial.

Amount expended during the fiscal year ending June 30, 1877	$19,778 46
Amount available July 1, 1877	99,747 77
Amount required for fiscal year ending June 30, 1879	218,500 00

(See also report of Maj. C. B. Comstock dated June 1, 1877.)

Very respectfully, your obedient servant,

H. M. ADAMS,
Captain of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX A.—STANDARDS OF LENGTH OF UNITED STATES LAKE SURVEY.

§ 1. The standards of length of the lake survey are—

1. Two steel-end measure yards, known as Clarke yards A and B.

They have the letters A and B engraved on them.

2. An inch graduated to tenths, and one-tenth to hundredths, on a slip of platinum let into the upper surface of a steel bar one inch square and an inch and a half long.

3. On the preceding, which are the standards, depend the lengths of a brass bar 15 feet long; and

4. The lengths of five brass yards, used in determining the length of the 15-foot brass bar.

§ 2. CLARKE YARDS A AND B.

These yards are bars of steel, 0.73 inch in depth and 0.50 inch in thickness. The ends are cylinders, 0.35 inch in length and 0.25 inch in diameter, co-axial with the bars.

The ends of the cylinders have agates firmly set in each, the surfaces of these stones being spherical surfaces, whose centers are at the opposite ends of the yards.

The standard distance is that between the central points of these small end surfaces.

Each yard is inclosed in an iron box, slightly larger than itself, the box having a hinged cover and sliding ends. In the bottom of each box are two equal levers, moving about horizontal axes at their centers, the ends of the levers thus giving four points of support for the yard resting on them, and bearing equal pressures, these points of support being at 5.2 inches and 10.9 inches from either end of yard. Four Fahrenheit mercurial thermometers accompany each yard, whose bulbs lie in niches for them in the interior sides of the iron boxes; their stems are bent at right angles, and are read through slits in the iron lids.

These yards are from a design suggested to me by Lieut. Col. A. R. Clarke, Royal Engineers. They were constructed by James Simms, of London, in 1873.

Yard A was compared by Lieutenant-Colonel Clarke at the ordnance survey office at Southampton with the standard yard, Y_{55} of the ordnance survey, eight times in four days in May, 1874, the temperature being between 51° and 52° F., and ten times in July, 1874, in four days, the temperature being between 62° and 64° F.

Yard B was compared eight times with Y_{55} in three days of May, 1874, at temperatures near 53°, and ten times in four days of July, 1874, at temperatures between 61° 7 and 62° 8.

The co-efficients of expansion of both A and B were determined by Colonel Clarke. The method used was to compare the yards with each other, one being kept at a high temperature by being placed in a box between tanks filled with hot water at a steady temperature, while the other was between tanks filled with cold water. The methods were essentially the same as those described in Colonel Clarke's work on "Comparisons of Standards of Length."

A at about 91° F. was compared ten times in three days with B at about 34°, and ten times in two days with B at about 57°. It was compared ten times in two days at about 34° F. with B at about 91°; ten times in two days at 55° with B at 91°; and ten times in two days at 56° with B at 57°.

These expansion-comparisons extended from April 18 to May 1, 1874.

The four thermometers accompanying each yard were carefully compared by Colonel Clarke with the ordnance-survey standard 3241, and their errors determined.

The comparisons of A and B with the ordnance-survey standard Y_{55} were each combined by least squares to obtain the lengths of A and B at 62°. The expansion-comparisons were combined in the same way, and from them the co-efficients of expansion of the two yards were obtained.

The following are Colonel Clarke's results:

Length of A at 62° F. in yards, $A = 0^{y}.99997695 \pm 0.00000013$.
Length of B at 62° F. in yards, $B = 0\ .99997111 \pm 0.00000016$.
Expansion for 1° F. of A in yards, $0^{y}.0000058740 \pm 0.0000000195$.
Expansion for 1° F. of B in yards, $0\ .0000058103 \pm 0.0000000197$.

In inches, the above values become—

Length of A at 62° F., $A = 35^{in}.999170 \pm 0.0000047$.
Length of B at 62° F., $B = 35\ .998960 \pm 0.0000058$.
Expansion for 1° F. of $A = 0^{in}.00021146 \pm 0.00000070$.
Expansion for 1° F. of $B = 0\ .00020917 \pm 0.00000071$.

The details of the comparisons are given in the lake-survey report, embodied in the Report of the Chief of Engineers for 1875.

§ 3. STANDARD INCH.

As accurate values of the micrometer-screws used in comparisons of lengths are indispensable, a standard inch was obtained from Mr. Simms, of London, for such determinations. It is divided into tenths, and the last tenth (from $0^{in}.9$ to $1^{in}.0$) is divided into hundredths. Each of the tenths and each of the hundredths had its value determined by comparison with the ordnance-survey standard foot, by Colonel Clarke. On this inch depend the values of the micrometer-screws used in all comparisons.

Colonel Clarke's values of the different divisions may be found in the lake-survey Report, embodied in Report of Chief of Engineers for 1876.

§ 4. FIFTEEN-FOOT STANDARD BAR.

This bar is a brass bar about 15 feet in length, its cross-section being $1^{in}.1$ by $0^{in}.33$. In each end an agate plate has been inserted in a dovetail, and is held in position by

burnishing the brass down upon it. The outer face of the agate plate coincides with the end of the bar.

On one broad face and near one end there is stamped "U. S. standard, 15 feet 0.0018 inches at 62° Fah. From yards Nos. 41, 42, 43, 44, 45. Expansion for 1° Fah. 0.0017 of an inch." The length of this bar is the distance between the middle points of the agate planes, when the stamped face being vertical and the inscription right side up, that top edge which is farthest from an observer reading the inscription is a straight line.

This 15-foot bar appears to have been received by the lake survey in 1852 with the Bache-Würdemann base apparatus.

The agate planes were not put in the ends of the bar till the winter of 1865-'66. They of course gave a new length to the bar. Nothing is known of the method by which the expansion of the bar for 1° F., which is stamped on it, was obtained. It is only an approximation to the true value. The length of the bar stamped on it, of course, is now incorrect.

In reference to the term "U. S. standard," it may be remarked that at one time the United States Treasury Department adopted the distance at 62° F. between the 27th and 63d inch, on a brass 82-inch scale, by Troughton and Simms, belonging to the Coast Survey, as a United States standard yard. Subsequently it was found that this so-called United States standard differed by about one-thousandth of an inch from the standard yard of England.

By law of 28th July, 1866, Congress, in legalizing the metrical system, adopted in round numbers the ratios which exist between the English and French standards of length, thus assuming that the yard, foot, and inch of the United States are the same as those of Great Britain. Hence, whenever these units are used in this paper the standards to which they refer are those of Great Britain.

The length of the 15-foot brass bar was derived from comparison with the five brass yards L. S., Nos. 6, 7, 8, 9, 10, placed end to end in a right line, and inclosed in a long narrow box, to prevent rapid changes of temperature, the 15-foot bar being in the same box beside and within 2 inches of the yards.

§ 5. FIVE BRASS YARDS.

These yards, used in determining the length of the 15-foot bar, were constructed for the lake survey at the office of weights and measures in Washington, in 1871, under the direction of Mr. J. E. Hilgard. They are all similar brass bars, and are marked respectively L. S., No. 6, 7, 8, 9, 10.

These yards are prisms one inch wide by six-tenths of an inch thick and thirty-four and seven-tenths inches long, having at each end an axial cylinder four-tenths of an inch in diameter and six-tenths of an inch long. In the ends of these cylinders agates are held by the brass, which is burnished down on them. The end surfaces of the agates are ground to a radius of 4 inches, the center of the sphere being in the axis of the bar. The distance between the middle points of these agate disks is taken as the length of the yard. These points are by construction in the prolongations of the axes of the end cylinders.

The values of these yards and their relative expansions have been determined by comparisons with each other and with the Clarke yards A and B at various times and widely-differing temperatures.

§ 6. COMPARATORS.

The comparators used are contact-level comparators, one by Würdemann and one by Stackpole. In each, a micrometer-screw moves in its own direction, a slide carrying the supports of a level having horizontal trunnions, which turn on the points of two steel screws; a vertical arm projecting from the under side of the level is in contact with one end of a sliding piece of steel, which at its other end abuts against the standard undergoing comparison, and moves parallel to the micrometer-screw on grooved rollers.

One end of the level is heaviest by an ounce or two, so that by the vertical arm underneath it the sliding piece is pressed with constant pressure against the end of the standard under comparison.

Any slight motions of this sliding piece can be read on the level by reading its bubble; larger motions up to 1 inch are read by moving the slide which carries the level by turning the micrometer-screw till the bubble is near the middle of the level, and then reading the level, the micrometer-head, and an inch scale on the slide. The value of one division of the micrometer-head is approximately $0^{in}.0001$, and of the level about $0^{in}.00001$ for the Würdemann comparator. One turn of the Würdemann screw is approximately $0^{in}.02$ and of the Stackpole screw approximately $0^{in}.01$.

In comparisons of two end-measure yards, the two comparators are mounted on a stout timber, so that their sliding pieces shall be horizontal with axes in the same straight line, the outer ends of the sliding pieces being nearly a yard apart. The

centers of the ends of the yards are then brought alternately between these sliding pieces, and the micrometer-heads are turned till the bubble is in the middle; both levels and micrometers are then read. The same being done for the second yard, the difference of readings gives the difference of length. The Stackpole comparator is kept as nearly at a constant reading as possible, thus throwing the measurement on the Würdemann comparator, which has the best level. For comparisons of 15 feet bars the same process is used, save that the comparators are then mounted on stable stone posts entirely disconnected with the floor on which the observer stands.

As in expansion-experiments quantities of nearly $0^{in}.1$ have to be measured, it is necessary to know the absolute values of one turn of the micrometer-screws and their periodic errors, with precision. These have been determined for the parts of the screws used, and the resulting values have been used in reductions.

The absolute values of one turn of the micrometer-screws were determined by mounting the standard inch on the comparator slide, and observing its successive divisions with a microscope as the micrometer-screw, which was read at each observation, moved them through the field.

The Würdemann comparator should be used only in the vicinity of or between the scale-readings, $0^{in}.1$ and $0^{in}.2$.

At $0^{in}.11$ its indications are to be multiplied by 1.004 to reduce them to inches. At this point the value of one revolution increases with increased reading at the rate of $\frac{1}{16700}$ part of its value per turn. Periodic error between $0^{in}.1$ and $0^{in}.2$ scale-reading has a maximum effect on either side of the mean of $0^{in}.00003$ or a total range of $0^{in}.00006$.

The periodic error was first determined by Bessel's method by Lieut. Lockwood, in 1874, and a later redetermination gave nearly the same value.

The readings of the Stackpole comparator at $0^{in}.47$ are to be multiplied by 1.003 to reduce them to inches.

The value of one turn diminishes at the rate of $\frac{1}{6200}$ part of its value per turn as the readings increase.

The periodic error of the screw amounts to $0^{in}.000019$ on each side of the mean, or has a total range of $0^{in}.000038$.

This screw is mainly used between the scale-readings $0^{in}.4$ and $0^{in}.5$.

§ 7. THERMOMETERS.

The thermometers on which the results in this paper depend are the following:

1st. Standard No. 230, made by Troughton & Simms, 1871.

2d. Casella standards Nos. 21472, 21473, 21474, 21475, 21476.

3d. Four thermometers, marked A_1, A_2, A_3, A_4, made by Simms, to accompany Clarke yard A.

4th. Four thermometers, marked B_1, B_2, B_3, B_4, made by Simms, to accompany Clarke yard B.

Standard 230 has a bulb $0^{in}.88$ long and $0^{in}.22$ diameter.

It is graduated from 20° to 220° F., in degrees, one degree having a length of $0^{in}.067$.

In the Casella thermometers, the length of the bulb is 1.0 inch and its external diameter is $0^{in}.31$. The stem is graduated from 21° to 129° F., into half-degrees, and a degree is $0^{in}.12$ in length.

In the A and B thermometers, the stem is bent at right angles to the bulb, which is $0^{in}.6$ long and $0^{in}.2$ in diameter. It is graduated to degrees, from 22° F. to 110°, the length of one degree being $0^{in}.055$.

The Casella thermometers having greater sensibility, and one of them, No. 21472, having been carefully studied by Prof. H. Ste. Claire Deville, it is taken as the standard. Professor Deville states that it has no errors of calibration exceeding 0°.1; that at 16° Cent. (=60°.8 F.) it differed from a tested standard of great perfection by but 0°.02 and but 0°.03 at 33° C., (=91°.4 F.)

No. 230 was compared with a standard at Kew Observatory in January, 1872, and the following corrections were found to the scale-readings, the stem being vertical:

Scale-readings, 32°, 42°, 52°, 62°, 72°, 82°, 92°, 212°.

Corrections, —0°.0, —0°.0, — 0°.1, —0°.0, + 0°.1, + 0°.2, + 0°.3, + 0°.1.

In September, 1873, its freezing-point was redetermined; the correction to 32° was then —0°.16. On November 17, 1873, its boiling-point was tested. The correction to 212° was + 0°.07, and on November 18 the correction to 32° was + 0.02.

December 19, 1873, it was	—0°.06
January 6, 1874, it was	—0°.07
March 8, 1875, it was	—0°.24
April 2, 1877, it was	—0°.31

Regnault's methods were carefully followed in all determinations, and numerous determinations were made at each date. The stem was always vertical.

As this thermometer is sometimes used horizontally, its error at 32° was determined in both positions at the same time; —0°.08 should be added to the vertical correction at 32° to give the correction at 32° with stem horizontal.

The following tables give the corrections, determined at the Kew Observatory in January, 1875, for the five Casella thermometers, the stems being either horizontal or vertical, and also the subsequent determinations of the freezing-points made at Detroit:

Casella thermometers, Fahrenheit, horizontal, corrections to be applied to scale-readings.

Date.		21472	21473	21474	21475	21476
	°	°	°	°	°	°
Kew, January, 1875	30	−0.0	......	......	......	......
Do	32	......	+0.1	+0.1	+0.1	+0.1
Do	35	−0.0	+0.1	+0.1	+0.1	+0.1
Do	40	−0.0	+0.1	+0.1	+0.1	+0.1
Do	45	+0.1	+0.1	+0.1	+0.1	+0.1
Do	50	+0.1	+0.1	+0.1	+0.1	+0.1
Detroit, March, 1875	32	+0.06	+0.13	+0.14	+0.15	+0.13
Detroit, December 23, 1875	32	−0.01	+0.08	+0.06	+0.07	+0.08
Detroit, December 30, 1876	32	−0.04	......	......	......	......

Casella thermometers, Fahrenheit, vertical, corrections to be applied to scale-raadings.

Date.		21472	21473	21474	21475	21476
	°	°	°	°	°	°
Kew, January, 1875	32	+0.1	+0.2	+0.2	+0.2	+0.2
Do	35	+0.1	+0.2	+0.2	+0.2	+0.2
Do	40	+0.1	+0.2	+0.2	+0.2	+0.2
Do	45	+0.2	+0.2	+0.2	+0.2	+0.2
Do	50	+0.2	+0.2	+0.2	+0.2	+0.2
Detroit, March 25, 1875	32	+0.10	+0.18	+0.18	+0.20	+0.16
Detroit, January 18, 1877	32	−0.01	......	......	......	......

The following table gives the corrections to be applied to the mean of the four A thermometers, and to the mean of the four B thermometers, to reduce their mean readings to Ordnance Survey standard 3241, a thermometer which has been very thoroughly studied by Lieut. Col. Clarke, who has given his methods and results in his work on comparison of standards of length.

Colonel Clarke states that the A and B thermometers were compared with 3241 with the greatest care. The table contains, besides Colonel Clarke's results, the results of later freezing-point determinations at the lake survey office.

Troughton & Simms A_1, A_2, A_3, A_4, B_1, B_2, B_3, B_4, horizontal corrections to be applied to scale-readings.

Date.		Mean of A_1, A_2, A_3, A_4	Mean of B_1, B_2, B_3, B_4.
	°	°	°
Lieutenant Colonel Clarke, April 15, 1874	32	−0.30	−0.28
Lieutenant-Colonel Clarke, May 2, 1874	32	−0.28	−0.24
Lieutenant-Colonel Clarke, April, 1874	52	−0.22	−0.13
Do	55	−0.18	−0.11
Do.	57	−0.17	−0.13
Do.	62	−0.22	−0.17
Do	93	−0.17	−0.13
Detroit, March, 1875	32	−0.37	−0.34
Detroit, December, 1875	32	−0.40	−0.38

The comparisons which fix the length of the 15 feet brass bar and its expansion depend almost entirely on the five Casella thermometers, and on the A and B thermometers. As the corrections of the A and B thermometers depend on ordnance survey standard 3241, while those of the five Casella thermometers depend on a Kew standard, a comparison between the A and B thermometers and the Casella thermometers becomes of interest. The freezing-point determinations, of course, give the absolute

errors of the 32° line. Comparisons were made between the standard 230 and the A and B thermometers and between 230 and 21472 in January, 1876, at 59°.5 F. This work gives us an indirect comparison between the A and B thermometers and 21472.

The results are as follows:

At 59°.5, the stems of the thermometers being horizontal, the mean of the readings of A_1, A_2, A_3, A_4 having had Colonel Clarke's corrections, and also the corrections for subsequent change of freezing-point applied to it, and 21472 having had the Kew correction and also the correction for subsequent change of freezing-point applied to it, 21472 then read 0°.06 F. greater than the mean of A_1, A_2, A_3, A_4.

Similarly, 21472 corrected reads, 0°.02 F. greater than the corrected mean of B_1, B_2, B_3, B_4, at 59°.5.

As the Kew corrections are only given to the nearest tenth of a degree, this agreement, taken in connection with Prof. Sainte Claire Deville's comparisons with another standard which gave no greater discrepancies, indicates that Casella No. 21472 is very accurately constructed, and that, so far as a mercurial thermometer is concerned, the probable error of its corrected indications is but a few hundredths of a degree. (21472 was also compared with the other Casella thermometers at 59°.5. The greatest discrepancy between the results and the Kew corrections was 0°.04.)

Whether it and all mercurial thermometers need appreciable systematic corrections between 32° F. and 100° F. to reduce their readings to those of an air-thermometer is not yet known. It is hoped to obtain this information at a later day.

§ 8. COMPARISON OF YARDS NUMBERS 6, 7, 8, 9, 10, WITH EACH OTHER.

For comparisons of the lake-survey yards Nos. 6 to 10 with each other and with Clarke yards A and B, the cylindrical ends of the brass yards rested in wyes, with a pressure of three or four ounces, nearly all their weight being carried by supporting spiral springs attached at one-fourth and three-fourths of the length of the yard. The comparators were firmly attached to strong timbers. The two yards under comparison were inclosed in a box with glass windows in its cover through which to read thermometers, and with slits with sliding covers through which the suspending wires passed, by whose aid, without opening the box, the yards under comparison were alternately placed in the wyes, which brought the centers of their ends in line with the axes of the sliding pieces of the comparators, and gave central contact for the end of the yard and the end of the sliding piece. The Clarke yards A and B remained in their cases, and were suspended and handled in the same way, the cases resting against adjustable stops, when exactly in the right position with reference to the comparators. Their cases were slightly inclined sidewise, so that these yards should slip so as to always take the same position in the case. Nearly all the comparisons were made in the cellar of the lake-survey office, where the daily range of the air temperature, caused mainly by the presence of the observers, rarely exceeded 2° or 3° F. Readings were usually taken about 9½ a. m. and 4 p. m., the room at other times being kept carefully closed when the temperature of the cellar was below 40° F. The rise of temperature in the box containing the yards under comparison, from the presence of the observers, during the time (about ten minutes) required for two or three comparisons, was usually about 0°. 3 F., as indicated by the thermometers under the wrapping of three thicknesses of flannel which incased the brass yards. For higher temperatures the effect of the presence of the observers was less.

If the temperatures of the brass yards had risen by the same amount as the temperatures of their thermometers, namely, 0°.3 F., the lengths of the yards would have increased by $0^{in}.00010$.

It it safe to say that they did not increase in length by more than one-half this amount, or $0^{in}.00005$, which must have been nearly the same for both; so that there is no probability that, during the ten or fifteen minutes of comparison of two brass yards, the difference of their lengths changed by so much as $0^{in}.00002$ on an average. As the yards were systematically alternated in position with reference to the observer this error was eliminated in the result.

From the insignificant effect that this small rise in temperature would have on the difference in length of two similar brass bars, all comparisons made on two brass yards are used, until the thermometer has risen by 0°.3 F. In early comparisons, at low temperatures, so many as five were obtained, occupying thirty minutes. Of these, only the first two or three have been used, as the thermometers rose 0°.6 or 0°.7 during the thirty minutes, and the temperatures of the two similar yards may not have changed equally.

In later work but two comparisons were usually made, each occupying from six to ten minutes, at 9.30 a. m. and 3 p. m.

In reducing the comparisons, those at the same period, and, therefore, at about the same temperature, have been combined so as to give a single equation of condition, to which a weight is assigned equal to the number of days of comparisons.

For this purpose, the mean of the observed differences of length is taken, and the

mean of the first readings of the thermometers in each set of comparisons, as the thermometers after the first reading are slightly affected by the presence of the observers, while the temperature of the yard has probably not sensibly changed.

The form of an equation of condition for yards Nos. 6 and 7 will be—

$$(6-7)_{t^\circ} = (6-7)_{62^\circ} - (62^\circ - t^\circ)\,(e_6 - e_7)$$

where 6 and 7 are the lengths of the two yards, t° the observed temperature, and e_6 and e_7 the expansions of 6 and 7 for 1° F.

Or, placing $(6-7)_{t^\circ} = n =$ observed difference of lengths;
$(6-7)_{62^\circ} = x =$ difference of lengths at 62°;
$e_6 - e_7 = y =$ difference of expansions for 1° F.;
$62^\circ - t^\circ = b$;

the equation of condition takes, for 6—7, the form—

$$n - x + by = 0$$

For 6 — 8, 6 — 9, &c., x and y would receive one, two, &c., primes.

The first column of the following table gives the dates of comparisons, the second the number of sets of comparisons, the third the number of days of comparisons, or the weights, the fourth the total range in the observed values of n, the fifth, sixth, seventh, and eighth, the equations of condition, and the ninth their residuals. The unit is one-millionth of an inch. The values of b show how far below 62° F. the mean temperature of each group of comparisons was.

Date.	Number of sets.	Number of days.	n	Range.	x	by	0	v	Temperature.
									°
1874—Jan. 14 to Feb. 12	18	9	− 1333	84	$-\ x$	$+\ 23.84\ y$	= 0	+ 21	37–41
June 18, 19	8	2	− 1339	92	$-\ x$	$+\ 1.74\ y$	= 0	− 8	60–61
1875—Dec. 7 to 13	12	6	− 1368	121	$-\ x$	$+\ 20.10\ y$	= 0	− 18	41–43
Nov. 29 to Jan. 5, 1876	24	14	+ 111	122	$-\ x'$	$+\ 21.43\ y'$	= 0	0	43–39
Aug. 7 to 19	10	4	+ 89	103	$-\ x'$	$-\ 0.28\ y'$	= 0	0	61–63
1874—Jan. 19 to Feb. 19	15	7	+ 1472	85	$-\ x''$	$+\ 23.08\ y''$	= 0	+ 3	39–40
June 23 to 30	8	3	+ 1509	106	$-\ x''$	$-\ 2.19\ y''$	= 0	+ 3	63–65
1875—Nov. 22 to 26	8	4	+ 1476	141	$-\ x''$	$+\ 18.47\ y''$	= 0	0	44–43
1874—Jan. 22 to Feb. 21	11	4	− 1596	63	$-\ x'''$	$+\ 21.82\ y'''$	= 0	+ 3	39–41
July 1, 2	8	2	− 1532	83	$-\ x'''$	$-\ 1.97\ y'''$	= 0	+ 11	63–64
1875—Dec. 14 to 21	12	6	− 1624	109	$-\ x'''$	$+\ 23.27\ y'''$	= 0	− 21	40–36
1874—Jan. 27 to Feb. 27	10	4	+ 2830	110	$-\ (x''-x)$	$+\ 23.50\ (y''-y)$	= 0	+ 8	38–40
July 7 to 15	8	3	+ 2830	79	$-\ (x''-x)$	$-\ 2.03\ (y''-y)$	= 0	− 3	63–64
Jan. 29 to Mar. 2	9	4	− 234	51	$-\ (x'''-x)$	$+\ 22.63\ (y'''-y)$	= 0	+ 15	39–40
July 16, 17	8	2	− 227	101	$-\ (x'''-x)$	$-\ 2.63\ (y'''-y)$	= 0	− 12	64–65
Feb. 4 to Mar. 7	9	4	− 3057	96	$(x'''-x'')$	$+\ 23.37\ (y'''-y'')$	= 0	+ 14	37–39

Solving the equations of condition by the method of least squares, and deducing the values of the unknowns and their probable errors, the following values result:

$$\begin{aligned}
(6-7)_{62^\circ} &= -1329 \pm 12 \\
(6-8)_{62^\circ} &= +\ 89 \pm 13 \\
(6-9)_{62^\circ} &= +1503 \pm 11 \\
(6-10)_{62^\circ} &= -1548 \pm 13 \\
e_6 - e_7 &= +\ 1.02 \pm 0.57 \\
e_6 - e_8 &= -\ 1.01 \pm 0.66 \\
e_6 - e_9 &= +\ 1.47 \pm 0.56 \\
e_6 - e_{10} &= +\ 2.36 \pm 0.62
\end{aligned}$$

In determining these values, no comparisons of No. 8 with another yard made prior to August 7, 1875, are used, as that yard had previously changed its length.

Five days' comparisons, March 1, 1874, at 39° F., gave $6-8 = -0^{in}.00010$
Two days' comparisons, June 1, 1874, at 61°.2 F., gave $6-8 = -0^{in}.00013$
Two days' comparisons, July 20, 1875, at 64° F., gave $6-8 = +0^{in}.00020$

In the interval between the last two comparisons, which show an evident change of length, as their difference far exceeds any possible error of comparison, the five yards placed end to end had been compared with the 15-foot brass bar.

During these comparisons the yards had been suspended by spiral springs, which allowed the end cylinders of the yards to rest in their guiding-wyes with but a few

ounces weight, and so left them with great ease of motion in the direction of their lengths. The idea at once suggests itself that in bringing the ends of the yards in contact, the shock of contact due the considerable mass of the yards had been sufficient to force in one of the agates at the ends of the yard No. 8 where the fitting had not been firm before, thus shortening the yard. These agates, in constructing the yards, were simply pressed into a cavity cut for them, and the brass at the ends of the cylinders burnished down around the agates. On August 2, 1875, I heated the ends of yard No. 8 to about 150 F., and then holding the yard vertical pressed the lower agate into a piece of soft wood, with a pressure of 20 or 30 pounds. Then the agate and end of the cylinder were rotated under the same pressure in a hole a little larger than the agate, the upper end of the hole having been reamed out so as to bear on the brass immediately around the agate and press it against the agate. Finally, the brass was burnished down upon the agate with a hand-burnisher. Both agates of No. 8 were treated in the same way.

Two days' comparisons, on August 7 and 9, 1875, gave, at 62°, $6-8=+0^{\text{in}}.00012$, which would indicate a lengthening of No. 8 by $0^{\text{in}}.00008$ since July 20, 1875. But in the previous comparisons the comparing-room was visited three or four times during the day, which makes it uncertain whether the temperatures of the two yards were precisely the same.

As the burnishing could hardly have lengthened the yard, it seems possible that the small apparent change in length subsequent to July 20, 1875, was due simply to temperature errors in the previous comparisons, and that the length of yard No. 8 was not sensibly affected by the burnishing process, or, in other words, that its agates are now stable.

The comparisons of the other yards at different dates give no indications of change in lengths.

The following are the results of comparisons of Nos. 6 and 8 at different dates:

1.	Nov. 30, 1871.	Temp., 55°.5 F.,	1 day's comparisons,	$6-8=$	$0^{\text{in}}.00000$
2.	March, 1874.	Temp., 39° F.,	5 days' comparisons,	$6-8\doteq$	$-0^{\text{in}}.00010$
3.	June, 1874.	Temp., 62° F.,	2 days' comparisons,	$6-8=$	$-0^{\text{in}}.00014$
4.	July 20, 1875.	Temp., 64° F.,	2 days' comparisons,	$6-8=$	$+0^{\text{in}}.00019$
	August 2, 1875.	Both agates of No. 8 burnished down.			
5.	August 9, 1875.	Temp., 62° F.,	2 days' comparisons,	$6-8=$	$+0^{\text{in}}.00012$
6.	August 9, 1875.	Temp., 63° F.,	2 days' comparisons,	$6-8=$	$+0^{\text{in}}.00009$
7.	Dec., 1876.	Temp., 41° F.,	14 days' comparisons,	$6-8=$	$+0^{\text{in}}.00011$

The comparisons of November 30, 1871, were not made under temperature conditions which could make precision certain, and their discrepancy with the second comparisons does not make it sure that yard 8 had changed length in the interval. It certainly changed length largely between June, 1874, and July, 1875, and may have changed very slightly while being burnished, although the difference of lengths on July 20, 1875, and August 9, 1875, while larger than the probable, is not larger than the possible errors in the comparisons made on only two days.

§ 9. COMPARISON OF BRASS YARD NUMBER 6 WITH CLARKE YARDS A AND B.

Having given the lengths and expansions of the other brass yards relatively to No. 6, it remains to explain how the absolute length and expansion of No. 6 were obtained from the Clarke yards A and B.

No. 6 was compared with A and B, and No. 7 with A. The yard A or B remained in its iron case, and, with its thermometers in their places, was put with the brass yard in the wooden box in which the brass yards had been compared with each other. The larger part of its weight was carried by suspending-springs, and its outer iron case rested against stops, adjustable so that the centers of its end surfaces should be in line with the axes of the sliding pieces or quills of the comparators. The case was slightly inclined, so that the yard within, under its own weight, should always assume the same position with reference to the case, and so with reference to the comparators. The brass yard was also suspended, resting its end cylinders in their supporting wyes. The two yards were alternately placed between the comparators, and comparator readings taken on both ends.

In the comparisons of No. 6 with A and B, at temperatures near or below 40° F., the three comparisons making a set required about twenty minutes. In this time the thermometer beneath the flannel wrapping of the brass yard usually rose about 0°.3 F., while those inside the cases of the yards A and B only rose about 0.°05 F.

In comparisons near 62° F. the rise in thermometers was about one-half the above amounts. Hence, as the thermometer-temperatures of No. 6 and A or B change very unequally, and as their expansions are very different, only the first comparisons and the first temperatures, on entering the comparing-room after an absence of several hours, were used in the reductions.

No comparisons were used in which the thermometer in contact with the brass yard and under three thicknesses of flannel differed by more than 0°.2 F. from the mean of the four thermometers inside the iron case of the Clarke yard; and as the presence of the observers for the two to four minutes before the thermometers were read may have slightly affected the thermometer with the brass yard, while its effect on those with the steel yards was insensible, the thermometers with the latter yards have been alone used in fixing the temperature of comparisons. No comparisons were used where the thermometers, with the Clarke yards, changed by more than 0°.4 F. between morning and afternoon comparisons, (9.30 a. m. to 4 p. m.)

No. 6 and A were compared with each other at three different periods, at temperatures varying from 37°.6 to 62°.8.

No. 7 and A were compared at about 33°. As the length and expansion of No. 7, with reference to No. 6, are known with great precision, the comparisons of 7 with A were reduced to those of 6 with A, giving a fourth group.

Each of these four temperature-groups of comparisons gave an equation of condition of the form

$$(6-A)_{t^\circ} = (6-A)_{62^\circ} - (62-t^\circ)\ (e_6-e_A),$$

in which t° is the observed temperature, e_A and e_6 the expansions of No. 6, and A for 1° F., and $(6-A)_{62}{}^\circ$, and (e_6-e_A), the unknowns, provided the temperatures were correctly measured.

But in some thermometers, which agree with an air-thermometer at 32° and 212° F., and which have no sensible errors of construction, it is known, in consequence of the dilatations of glass and mercury depending on both the first and second powers of the temperature, that at other readings they may differ sensibly from an air-thermometer. An attempt has been made to have one of the lake-survey thermometers compared with an air-thermometer, but as yet no results have been received. In the comparisons with each other of the brass yards Nos. 6, 7, 8, 9, 10, as their relative expansions, are very small, no sensible error is introduced into their relative lengths by an error of 0°.1 or 0°.2 F. in measuring their common temperature. But in determining the relative lengths of A and No. 6, an error of 0°.2 F., in determining their common temperature, would introduce an error of 0in.00002, a quantity larger than the probable error of comparison.

If such a systematic correction should be needed to make the lake-survey thermometers agree with an air-thermometer, it may be taken with sufficient accuracy between 32° and 62° F., as proportional to the excess of temperature over 32°, and its form will be $\Delta\ (t^\circ-32^\circ)$.

The equation of condition from a group of comparisons will then take the form

$$(6-A)_{t^\circ} = (6-A)_{62^\circ} - \{62^\circ - [t^\circ + (t^\circ - 32^\circ)\ \Delta]\}\ (e_6 - e_A);$$

which may be written

$$-n + x - (a - b\ \Delta)\ y = 0,$$

in which n is the mean difference of lengths of the two yards, derived from a group of comparisons at nearly the same temperatures of which t° is the mean; x is the unknown difference of length at 62°, and y the unknown relative expansion. The weight of each equation is equal to the number of its comparisons.

The following table gives the date of comparisons, the number of days of comparisons, the number of comparisons, the temperature-range during the comparisons, the equations of condition, and their residuals, Δ being neglected. The unit is the millionth of an inch.

Comparisons of No. 6 with A.

Date.	Number of days.	Number of comparisons.	Temperature.	Equations of condition.	Residuals.
1874—Dec. 24 to Jan. 4, 1875	6	6	42° to 37°	$-2847-x+(22.25-7.75\ \Delta)\ y=0$ ...	-4
1875—August 20 to 23	3	11	63° to 60°	$+405-x+(0.09-29.91\ \Delta)\ y=0$ ..	-8
October 2 to 6	5	9	54° to 55°	$-538-x+(6.65-23.35\ \Delta)\ y=0$ ...	$+13$
January 18 to 23 .... (No. 7 and A.)	6	10	33° to 34°	$-3820-x+(28.89-1.11\ \Delta)\ y=0$ ...	-1

The following table gives similar data for comparisons of No. 6 and Clarke yard B:

Comparisons of No. 6 with B.

Date.	Number of days.	Number of comparisons.	Temperature.	Equations of condition.	Residuals.
1875—January 6 to 15	6	8	36° to 33°	$-3473-x'+(27.72-\ 2.28\,\Delta)\,y'=0$ ...	$+1$
October 7 to 8	2	4	55° to 54°	$-\ 414-x'+(\ 6.81-23.19\,\Delta)\,y'=0$ ...	$+4$
November 3 to 9	6	8	48° to 47°	$-1508-x'+(14.25-15.75\,\Delta)\,y'=0$ ...	-3

In this table x' and y' have replaced the x and y of the preceding table, as yard B has replaced yard A.

Solving the above equations by least squares, the following values result:

$$x=(6-\text{A})_{62}{}^{\circ}=+426-4408\,\Delta\pm6.$$

$$x'=(6-\text{B})_{62}{}^{\circ}=+578-4385\,\Delta\pm4.$$

$$y=e_6-e_{\text{A}}=146.94-146.94\,\Delta\pm0.32.$$

$$y'=e_6-e\ \ =146.17-146.17\,\Delta\pm0.21.$$

The unit being a millionth of an inch, and the probable errors being derived from the equations of condition when Δ is taken as zero.

If the value of x above be subtracted from that of x', we have $\text{A}-\text{B}=152$, the terms in Δ being neglected, as Δ is very small and its co-efficients nearly equal.

Referring to Colonel Clarke's values of A and B, § 2, we find $\text{A}-\text{B}=211$, differing from the value just found by 59. Both Colonel Clarke's and the lake-survey determination of this difference are indirect—that is, they are each obtained by comparisons with a third yard.

Still the difference is larger than would be supposed from the probable errors of the comparisons, and it is hoped hereafter to make a direct determination of its value.

If equal weights were given to the two determinations of the difference, the two results would differ from their mean by but $\frac{1}{1200000}$ of a yard, a quantity that is not large in such work.

Subtracting y' from y we have

$$e_{\text{B}}-e_{\text{A}}=+0.77.$$

Colonel Clarke's value (§ 2) is

$$e_{\text{B}}-e_{\text{A}}=-2.33.$$

Were the mean of these two values to be adopted, it would require a change in the values for the expansions of A and B, found by Colonel Clarke, of $\frac{1}{135}$ part.

Adding now the value of $(6-\text{A})_{62}{}^{\circ}$ to the length of A at 62° F, given by Colonel Clarke, (§ 2,) there results the length of No. 6 at 62° F.

$$\text{No. }6=35^{\text{in}}.999596\pm8-0.004408\,\Delta.$$

Adding the value of $(6-\text{B})_{62}{}^{\circ}$, above, to the length of B at 62° F, given by Colonel Clarke, (§ 2,) there results the length of No. 6 at 62° F.:

$$\text{No. }6=35^{\text{in}}.999538\pm7-0.004385\,\Delta.$$

The probable errors having, in both cases, been obtained by neglecting Δ as insignificant. These values differ by $0^{\text{in}}.000058$; a quantity larger than the probable errors of the separate values. The mean of the two values must be taken, and the probable error of the mean must be derived from its differences from the two values.

There results, then, for the length of No. 6 at 62°, from the data at present (April, 1877) available,

$$\text{No. }6=35^{\text{in}}.999567\pm0^{\text{in}}.000020-0.004396\,\Delta.$$

The probable error being obtained by supposing $\Delta=0$, and being $\frac{1}{1800000}$ part of the length.

From § 2 e_A the expansion of yard A for 1° F. is $0^{in}.00021146$. From § 9 $e_6 - e_A$ is $0^{in}.00014694\ (1 - \Delta)$ and adding the value

$$e_6 = 0^{in}.0003584 - 0.00014694\ \Delta \text{ results.}$$

Again, deriving e_6 from $e_B + (e_6 - e_B)$, we have

$$e_6 = 0^{in}.00035534 - 0.00014617\ \Delta.$$

Taking the mean of these two values, derived from yards A and B respectively, we have

$$e_6 = 0^{in}.0003569 - 0.00014656\ \Delta \pm 0.00000103.$$

Subtracting from the length of No. 6 its excesses over Nos. 7, 8, 9, 10, (§8,) there result the following lengths of these yards at 62° F.:

$$\begin{aligned}
\text{No. } 7 &= 36.000896 \pm 0.000023 - 0.004396\ \Delta.\\
\text{No. } 8 &= 35.999478 \pm 0.000024 - 0.004396\ \Delta.\\
\text{No. } 9 &= 35.998064 \pm 0.000023 - 0.004396\ \Delta.\\
\text{No. } 10 &= 36.001115 \pm 0.000024 - 0.004396\ \Delta.
\end{aligned}$$

Summing these values, and deducing the probable error, we have

$$\text{Yds. } (6 + 7 + 8 + 9 + 10) = 179.999120 \pm 0.000103 - 0.02198\ \Delta.$$

If the relative expansions, $e_6 - e_7$, $e_6 - e_8$, $e_6 - e_9$, and $e_6 - e_{10}$, be subtracted in succession from the value of e_6, derived from the Clarke yards, we should have values for the absolute expansions of those yards. Summing those values, we have a value for the expansion of the five yards, when placed in contact, end to end, their axes being in the same right line. That value is

$$e_{6+7+8+9+10} = 0^{in}.0017807 \pm 0.0000053 - 0.0007328\ \Delta.$$

§ 10. COMPARISONS OF FIVE LAKE-SURVEY YARDS (NOS. 6 TO 10) PLACED END TO END WITH 15 FEET BRASS BAR.

In these comparisons the two comparators were mounted on stone posts, about 15 feet apart, their sliding pieces being in the same right line.

The bar and yards, in the comparisons prior to June, 1875, were placed side by side in a closed wooden box, parallel to each other, and 2 inches apart.

The 15-feet bar rested on rollers 18 inches apart, and was provided with side-guide screws to limit its side motion and to aid by slight pressure in its alignment. By raising or lowering its rollers, and by moving its guide-screws, the bar, while remaining free to move, was made straight; its straightness being tested with a silver wire strained by a known weight, the wire being vertically over one of the upper edges of the bar. The side of the 15-feet bar was brought into the vertical plane of the wire to within $0^{in}.01$, and the top of the bar made parallel to the wire after the latter was corrected for its computed sag within the same error. The 5 yards placed end to end were each supported at ¼ and ¾ of their lengths by spiral springs, so adjusted as to carry nearly all the weight of the yards, leaving only three or four ounces to be supported by the wyes in which the end cylinders of the yards rested. The spiral springs supporting the end yards were so inclined that these yards each pressed toward the central yard with a force of about one pound, thus securing contact between the ends of the yards. The axes of the end cylinders of the yards were brought into the same right line by adjusting the wyes in which they rested. To bring them into the proper position, with reference to a vertical plane, a small piece of a semi-cylinder of the same diameter as the end cylinders of the yards had a point in its axis marked on its diametral plane surface. This semi-cylinder was placed in the wyes in succession, and each of the latter was moved sidewise till the point was directly under a stretched fine silver wire 16 feet long which vibrated just above the point.

To bring them into the proper position with reference to a horizontal plane, a level was fastened to the upper surface of one of the yards which at once gave the means of determining the difference of height of two wyes a yard apart, and of adjusting them to the proper height by means of their adjusting-screws.

As where two yards met there were two wyes very near each other, they were adjusted with reference to each other by a smaller level. Prior to July 1, 1875, the box containing the bar and yards, parallel to each other and about 2 inches apart, was mounted on two trestles of the base apparatus, which gave lateral motion sufficient to bring the 15-feet bar and the yards alternately between the comparators.

Subsequent to that date the bar and yards were mounted an a T-shaped iron beam about an inch apart, the whole being inclosed in one of the long boxes of the expansion apparatus, the necessary lateral motion for comparisons being obtained by running the track of that apparatus sideways.

The first comparisons of 15-feet bar with lake-survey yards Nos. 6, 7, 8, 9, 10, were made in a room on the first floor of the lake-survey office on 17 days, between February 26, 1872, and June 24, 1873. The daily temperature range in this room is large, though less than that of the external air. As the cross-sections of the yards are 1^{in} by

$0^{\text{in}}.6$, while that of the 15-feet bar is $1^{\text{in}}.1$ by $0^{\text{in}}.33$, the cross-section of the yards is two-thirds greater than that of the bar.

In changing temperatures that of the yards will always lag behind the temperature of the bar, so that the temperature changes should be kept far below those of the ordinary diurnal ones. For this reason these comparisons were not considered satisfactory. They were given in the Lake Survey Report for 1874; the difference at 62° F., bar-yards, being found $0^{\text{in}}.00839$.

A comparing-room was subsequently established in the cellar of the lake survey-office, where the daily range in the air temperature outside the closed box containing the yards and bar was only 2° or 3° F., this being partly caused by the presence of the observers.

Fourteen days' comparisons, between December 10 and December 30, 1873, at a mean temperature of 42°.81 F., gave bar-yards $= 0^{\text{in}}.00829$.

Three days' comparisons, between July 21 and 24, 1874, gave at a mean temperature of 64°.7 F. bar-yards $= 0^{\text{in}}.00837$.

Between June 1, 1874, and July 20, 1875, yard No. 8, as compared with No. 6, appeared to have shortened by $0^{\text{in}}.00033$, there having been two days' comparisons at the first and two at the last of those dates, the first giving at 61°.2 F. $6 - 8 = -0^{\text{in}}.00013$, and the second giving at 63°.9 F., $6 - 8 = +0^{\text{in}}.00020$.

In both sets of comparisons the room was visited too frequently (three or four times a day) for the best work, but it is improbable that either of these values is erroneous by so much as $0^{\text{in}}.00005$.

The first value agrees with a value determined by five days' comparisons on March 1, 1874.

It is uncertain at what time the change in length of yard No. 8 occurred. It may have been before March, 1874, or after June, 1874, and it therefore throws uncertainty on all comparisons of the 15-feet bar with the five yards prior to August 2, 1875.

On that date strong pressure was applied to the end agates of No. 8, the brass around them was burnished down, and No. 8 was recompared with No. 6; the resulting difference $(6-8)_{62^\circ} = +0^{\text{in}}.000089$ has already been given in § 7.

The 15-feet bar and the five yards were again compared on August 12, 13, 14, 1875, at a temperature of 63° F., and on 26 days between February 28, 1876, and April 7, 1876, at temperatures varying from 34°.7 to 38°.5 F.

From these two sets of comparisons the difference at 62° F. (bar-yards) has been found and the relative expansion of the bar and the five yards.

Each comparison gave an equation of condition of the form—

$$D_{62^\circ} + (t^\circ - 62^\circ)\, e - n = 0.$$

in which D_{62° is the excess of length of bar over that of the five yards in contact in a straight line; t° is the corrected temperature of the comparison; e is the excess of expansion of bar over yards for 1° F., and n is the observed difference of length of bar and 5 yards corrected for periodic error of comparator-screw.

The following are the equations of condition, with dates and residuals:

Date.	Equations of condition.	Residuals.
1875.	*Inches.*	*Inches.*
Aug. 12	$D_{62} + 0.8e - 0.00872 = 0$	+0.00012
13	$D_{62} + 0.9e - 0.00875 = 0$	+ 9
14	$D_{62} + 0.5e - 0.00905 = 0$	− 21
1876.		
Feb. 28	$D_{62} - 26.0e - 0.00883 = 0$	−12
29	$D_{62} - 25.8e - 0.00878 = 0$	− 7
Mar. 1	$D_{62} - 26.0e - 0.00873 = 0$	− 2
2	$D_{62} - 26.4e - 0.00871 = 0$	− 1
3	$D_{62} - 26.6e - 0.00872 = 0$	− 2
4	$D_{62} - 26.5e - 0.00888 = 0$	−18
6	$D_{62} - 25.2e - 0.00890 = 0$	−19
7	$D_{62} - 23.8e - 0.00891 = 0$	−19
9	$D_{62} - 24.1e - 0.00880 = 0$	− 8
10	$D_{62} - 24.0e - 0.00863 = 0$	+ 9
15	$D_{62} - 25.3e - 0.00855 = 0$	+16
16	$D_{62} - 25.4e - 0.00861 = 0$	+10
18	$D_{62} - 26.4e - 0.00866 = 0$	+ 4
21	$D_{62} - 27.3e - 0.00865 = 0$	+ 5
22	$D_{62} - 27.2e - 0.00859 = 0$	+11
23	$D_{62} - 26.8e - 0.00871 = 0$	− 1
24	$D_{62} - 26.3e - 0.00858 = 0$	+12
25	$D_{62} - 25.8e - 0.00865 = 0$	+ 6
27	$D_{62} - 25.4e - 0.00860 = 0$	+11
30	$D_{62} - 26.0e - 0.00868 = 0$	+ 3
Apr. 4	$D_{62} - 25.0e - 0.00864 = 0$	+ 7
5	$D_{62} - 24.3e - 0.00874 = 0$	− 3
6	$D_{62} - 24.1e - 0.00876 = 0$	− 4
7	$D_{62} - 23.6e - 0.00876 = 0$	− 4

From February 28 to March 10, 1876, inclusive, the yards were next the observer; from March 15 to April 7 the bar was next the observer.

Solving these equations of condition by least squares, we have: Bar longer than the five yards, at 62°, or

$$D_{62} = +0^{in}.008843 \pm 0^{in}.00004$$

and expansion of 15-feet bar for 1° F. greater than that for five yards, by

$$0^{in}.0000052 \pm 0^{in}.0000017$$

In § 8 the sum of the expansions of the five brass yards, as derived from their comparisons with Clarke yards A and B, and each other, and from Colonel Clarke's values of the expansions of A and B, was given—

$$e_{6+7+8+9+10} = 0^{in}.0017807 \pm 0^{in}.0000053 - 0.0007328\,\Delta$$

Adding to this the value of excess of expansion of bar over five yards just given. we obtain a value for the expansion of the 15-feet bar for 1° F. derived from that of the Clarke yards; it is—

$$0^{in}.001786 \pm 0^{in}.0000056 - 0.0007328\,\Delta$$

The value derived from the direct expansion experiments given in § 11 is—

$$0^{in}.001795 \pm 0^{in}.0000016$$

When it is remembered that the first value is affected by the errors of comparisons of seven different yards, its agreement with the direct value may be considered satisfactory.

Adding to the sum of the lengths of the yards Nos. 6, 7, 8, 9, 10, given in § 8, namely, Nos. $6+7+8+9+10 = 179^{in}.999120 \pm 0^{in}.000103 - 0.02198\,\Delta$, the value—

$$D_{62°} = +0^{in}.008843 \pm 0.000040,$$

there results for length of 15-feet brass bar at 62°—

$$\text{Bar}_{62°} = 180^{in}.00796 \pm 0^{in}.000111 - 0.02198\,\Delta.$$

It has previously been stated that 14 days' comparisons of 15-feet bar with the five yards in December, 1873, at a mean temperature of 42°.81 gave: Bar—yds. $= 0^{in}.00829$.

The 24 days' comparisons, beginning February 28, 1876, gave at 36°.2—

$$\text{Bar} - \text{yards} = 0^{in}.00871,$$

giving, when reduced to the same temperature, a relative increase in length of bar of $0^{in}.00045$.

Of this increase, $0^{in}.00023$ is due to the shortening of brass yard No. 8 between June, 1874, and August, 1875. See § 8.

The rest, $0^{in}.00022$, may be accounted for by supposing the shortening of No. 8 to have partly occurred before June, 1874, by supposing all the yards have shortened slightly, or by supposing that the brass 15-feet bar has lengthened. But as it amounts to but $\frac{1}{820000}$ part of the length of the bar, it may possibly be due to errors of comparisons.

In discussing the expansion of the 15-feet brass bar, (§ 10,) it will be seen that the comparisons of the brass bar with the iron bar packed in ice also indicate an increase in length in the brass bar after it had been heated from 32° to about 100°, which temperature it probably reached, of about the same amount.

If the modulus of elasticity of cast brass be taken as 6450 kilograms per square millimeter, and its breaking strength as 12 kilograms, the force needed to stretch it by $\frac{68}{100000}$ of its length would be about 4.4 kilograms per square millimeter, or more than one-third of its ultimate strength. But heating a brass bar from 32° F. to 100° F. stretches it by this amount, ($\frac{68}{100000}$ of its length,) and the question arises whether this heating may not produce a temporary or permanent change of length. No positive conclusions can be drawn, as the apparent change is so small that it may possibly be due to errors of comparison, its proportional amount little exceeding that of the errors in good comparisons of two yards à trait.

§ 11.—EXPANSION OF 15-FEET BRASS BAR FOR 1° FAHRENHEIT.

A determination of the expansion for 1° F. of the standard 15-foot brass bar was made in the winter of 1870-'71. Two methods were adopted. In the first, the comparators being firmly fixed in the tops of stone piers, their stability was assumed. On consecutive days the bar was brought between the comparators, the room and bar on the first day being at the natural temperature, and on the next the room was heated by a stove, so that its temperature and that of the bar were from 25° to 45° F. higher. The distance between the middle points of the comparators being taken as unchanged, the difference of the comparator readings for hot bar and cold bar, allowance being made for the expansion of half of each comparator, gave the change of length of the bar.

Temperatures of the bar were given by six thermometers.

The difference in lengths of the bar, divided by the corresponding differences of temperatures, gave the expansion for 1° F.

§12. The second method was to clamp five yards together, end to end, thus forming a compound bar about 15 feet long, to surround this compound bar with broken ice, thus making its temperature and length constant, and then to compare the 15-foot bar with it, both at the natural temperature of the room and with that temperature raised about 30° F.

The value obtained for the expansion of the 15-foot brass bar by both methods was $0^{in}.00174$. (See Lake Survey Report for 1871.)

The objection to the first method is, that the perfect stability of the piers during changing temperatures is uncertain, and to both methods, that the temperature of a brass bar like the standard cannot be determined from mercurial thermometers in contact with it with any such accuracy as $0^{\circ}.1$ F. or $0^{\circ}.2$ F., unless the temperature of the bar and its surroundings has been kept within a few tenths of a degree of a stationary temperature for several hours. At the high temperatures this could not be effected with means then at command. When the air temperature rises through many degrees to a maximum, the temperature of the bar lags behind that shown by the thermometers, so that the indicated temperature change is too great, giving too small an expansion. Subsequent work on this bar shows that at the high temperatures, (70° to 80° F.,) when the bar had its maximum length, its temperature was about 1° below that of the thermometers with it.

Later experience threw doubt on the accuracy of the value, and a few trials in July, 1874, of a method slightly differing from the first, made it nearly certain that the above value was somewhat too small. This new method was to place the 15-foot bar between the comparators, the temperature of the comparing-room being steady at about 64° F., to let it remain at least 16 hours, so that its thermometers might give its true temperature, then to read the comparators, and immediately to remove it to another room, when, for 4 hours, it was packed in ice. At the end of this time it was, while still packed in ice, placed between the comparators, which were again read. This process assumed the stability of the comparators for 4 hours of pretty steady temperature.

Results were obtained on five days for the expansion of the 15-foot bar for 1° F., which varied from $0^{in}.001781$ to $0^{in}.001809$, their mean being $0^{in}.0017959$.

§ 13. It being now pretty certain that the value found for the expansion of this bar in 1871 was not sufficiently precise, I decided to attempt the careful redetermination of this important constant, and to use the method described by Capt. A. R. Clarke, Royal Engineers, in "Comparisons of Standards of Length," making such modifications as would adapt it to the inconvenient cellar in which we had to work.

The important point in Captain Clarke's method is, that he secures steady temperatures for each of two bars for several hours by placing them in closed boxes, whose sides are copper tanks, through which water of any desired constant temperature runs.

The method adopted, differing somewhat from Captain Clarke's, was to use a second bar constantly packed in ice, and to compare the 15-foot brass bar at temperatures of 32° and 90° F. with this second bar.

For the second bar, an iron bar, whose cross-section was $1^{in}.1$ in depth by $0^{in}.33$ in thickness, had mill cylindrical steel pins firmly screwed into its ends; the outer ends of these cylinders were planes, very nearly at right angles with the axis of the bar, and at such a distance apart as to give the two bars the same length at about 91° F.

This iron bar was mounted on ten adjustable rollers, in a semi-cylinder of quarter-inch boiler-iron, which was 15 feet long, and 4 inches in diameter. This semi-cylinder was packed with pounded ice so that the bar should be entirely covered, one upper edge of the bar being tested after the ice was in to see that it did not deviate from a right line by more than one-hundredth of an inch. When the ice was well rounded over the bar—fifty pounds were required—it was replaced when the weight had diminished by about twelve pounds.

The semi-cylinder was supported at one-fourth and three-fourths of its length. To test its stiffness, five pounds were hung at one end, giving a deflection of but $0^{in}.007$.

Accordingly it was assumed that the varying ice-load produced no injurious flexure of the bar due to change of form of the supporting semi-cylinder.

As the points of support for the iron bar were but 19 inches apart, and the greatest ice-load on top of the bar between two points of support could scarcely exceed half a pound, the length of the axis of the bar could not be sensibly changed by variations in this load.

For cold comparisons, the brass bar was also packed in ice, while resting on its supporting T-shaped iron bar, which was stiff as the semi-cylinder already described.

For comparisons of brass bar hot with iron bar in ice, the brass bar was placed in a long, narrow, closed box, its ends only projecting very slightly from the ends of the box. The box had a cloth-lined wooden cover, and its sides were formed by two long metal tanks, each 5 inches in depth by $2^{in}.7$ in thickness, the faces next the bar being of copper. In the interior of each tank was a 2-inch iron pipe running along the bottom of the tank, and then returning along the top; through this pipe the hot water flowed.

The brass bar was supported on adjustable rollers, on top of a stout T-shaped iron bar, nearly 15 feet long, lying between the tanks.

The two bars in their boxes, parallel to each other and about 3 feet apart, rested on a very stable, heavy truck, whose smooth lateral motion on iron rails brought, alternately, the centers of the end of one bar or the other between the comparators, mounted on their stone posts.

The bars were adjustable both horizontally and vertically, so that when once adjusted each could at once be brought into proper position with reference to the comparators, by motion of the truck alone, whose displacement was limited by adjustable stops, and a comparison of the two bars could be made within five minutes.

Hot and cold water were run into a large cask at such rates as to give a pretty steady temperature when well stirred; from this, with a slight head, the water flowed through flexible tubes into the iron pipes contained in the tanks.

In the first experiments, although the temperature of the water in the mixing-cask could be kept at a temperature varying from 99° to 101° F. by properly adjusting the flow into it of hot and cold water, yet the flow through the pipes in the tanks was not steady, the slit-opening of the stop-cock being clogged by the impurities in the water. The form of this opening was changed and the water passed through a cloth strainer. Afterward there was no difficulty in keeping the temperature of the hot box at a temperature of about 90° F., without a greater variation for the middle thermometer than 0°.9 in eight hours.

The thermometer near the end where the water entered and left the tank was usually 0°.2 or 0°.3 greater than at the corresponding place at the other end.

At first some vapor from the wood of the hot-box condensed on the under side of the glass windows in the cover through which the thermometers beside the brass bar in the hot box were read, making the reading uncertain. Chloride of lime was used to absorb this vapor until the boxes were dry, although it is objectionable on account of danger of rust.

The temperature of the cellar being about 35° F. below that of the hot bar, which was about 90° F., and the ends of the brass bar being exposed for comparison, the temperature of the ends of this hot bar were somewhat affected by the cold air outside.

The interior of the hot box near its ends was stuffed with cotton, but a thermometer within 3 inches of the ends of the bar still stood at from 2° to 3° below those at the middle. While these thermometers doubtless gave a temperature lower than that of the brass they touched, it was not deemed safe to neglect so large a difference. A stove was brought into the cellar, and during hot comparisons the temperature of the room was raised to about 85°. The temperature of the water as it left the tanks was lowered to 90° F., giving about 89° for the temperature of the bar. After this, the thermometer near the end of the bar gave a temperature but about 0°.5 lower than that near the middle.

The thermometers used were the five Casella standards Nos. 21472 to 21476, already described. They can be read to 0°.02 F.

The mean temperature of the 15-foot bar during hot comparisons was determined as follows: The early experiments with thermometers in various positions had shown that thermometers distributed along the bar agreed within two or three tenths of a degree until they approached within 18 inches of the ends of the bar, when they began to fall, standing at the ends of the bar 2° or 3° lower. By heating the air in the cellar to 85° this fall was reduced to about 0°.5. After this, if the thermometer readings on the bar are plotted as ordinates, the distances along the bar being abscissas, the curve will be nearly straight to within 12 or 15 inches of the ends of the bar. In the comparisons used, the thermometers were placed on each side of the middle of the bar at 22½ and 72 inches from it, and a fifth at 3 inches from one end. Means of the readings of each thermometer were used for each comparison to plot the temperature curve (whose general form was already known) for that comparison. The mean ordinate of this curve was taken as the temperature of the bar for this comparison.

The brass 15-foot bar and the iron bar were compared with each other, both being packed in ice, on ten days between April 21 and May 1, 1875, as shown in the following table:

Date.	Iron bar—brass bar, both in melting ice.
	Inch.
April 21, 1875	0. 038801
April 22, 1875	0. 038991
April 23, 1875	0. 038794
April 24, 1875	0. 038794
April 26, 1875	0. 038880
April 27, 1875	0. 038803
April 28, 1875	0. 038873
April 29, 1875	0. 038954
April 30, 1875	0. 038955
May 1, 1875	0. 038966
Mean	0. 038881 ± 0. 000017

The resulting excess of length of the iron bar is $0^{in}.038881 \pm 0.000017$ at 32°, the probable error being derived from the discrepancies between the daily results and their mean just given.

After the hot comparisons had been made, the two bars, both packed in ice, were again compared with each other on four days from June 21 to June 25, 1875, as shown in the following table:

Date.	Iron bar—brass bar, both in melting ice.
	Inch.
June 21, 1875	0. 038595
June 23, 1875	0. 038711
June 24, 1875	0. 038535
June 25, 1875	0. 038664
Mean	0. 038626 ± 0. 000026

The resulting excess of length of the iron bar was $0^{in}.038626 \pm 0^{in}.000026$, differing from the previous value by $0^{in}.000255$. This difference is larger than the probable errors would lead one to expect. But it is only $\frac{1}{700000}$ part of the length of the bar, a quantity which, in view of the many difficulties in such work, is too small to make it certain that the bar changed length during the hot comparisons. As such a change is however possible, equal weights have been given to the values obtained for excess of length of iron bar in ice over brass bar in ice, before and after hot comparisons, and their mean $0^{in}.038754 \pm 0^{in}.000086$ has been adopted as the most probable value of their difference in length at 32° F.

The comparisons of the brass 15 feet standard bar with the five brass yards, Nos. 6 to 10, given in § 10, also indicate a lengthening of the brass 15 feet standard at about this time and by about the same amount, but, as already stated, the apparent discrepancy scarcely exceeds the possible errors in good work.

The comparisons between the iron bar packed in ice and the 15 feet standard brass bar at a temperature of about 90° were 19 in number on ten days, between May 26 and June 18, 1875, but only those on or after June 10 were used in obtaining the final value of the expansion. They were 12 in number, and on reducing them to a common temperature the residuals gave a probable error for their mean of ± 0.000003. The resulting expansion of brass bar for 1° F. from each hot comparison is given below under the heading *e*.

It has previously been stated that the early hot comparisons were not considered satisfactory because, at first, the flow of hot water was not steady or the temperature of the air in the cellar was not near enough to that of the exposed ends of the brass bar. For these reasons, no hot comparisons prior to June 10, 1875, were used in adopting a final value for the expansion, but the values resulting from the previous comparisons are given in the following table, to show how little effect those causes of error produced. The table gives the expansion resulting from each comparison of brass bar, hot, with iron bar in ice.

Date.	Temperature range.	e.
1875.	°	*Inches.*
May 26	59. 20	0. 0018028
May 28	59. 92	17964
May 28	59. 24	17946
June 2	59. 25	17948
June 2	59. 33	17996
June 4	61. 33	17997
June 8	65. 22	17975
June 10	56. 96	17939
June 10	56. 96	17923
June 10	56. 70	17947
June 14	57. 68	17914
June 14	57. 51	17930
June 14	57. 73	17946
June 16	57. 26	17962
June 16	57. 41	17967
June 16	57. 07	17960
June 18	56. 59	17984
June 18	57. 05	17996
June 18	57. 10	17984

The results of the hot comparisons on and subsequent to June 10, 12 in all, were combined with the results of cold comparisons, and the mean value of the resulting expansions was taken as the most probable value. That value is mean expansion of 15 feet standard brass bar between 32° and 89°.15 F. for 1° F.

$$e = 0^{in}.001795 \pm 0^{in}.0000016.$$

This probable error is obtained by dividing the probable error in the determination of the change of length of the brass bar, namely $\sqrt{(.000086)^2+(.000030)^2}$ by 57°.15, and assumes that there is no constant error in the determination of this difference of temperature.

As the temperature of 32° was obtained directly from melting ice, there is no thermometer-error in it. But at the high temperatures, whose mean was 89° 15 F., there may be a small correction necessary to reduce the standard thermometer to an air-thermometer. Suppose it of the form $(t^{\circ} - 32^{\circ})\Delta$. The corresponding correction to the expansion will be closely enough

$$de = 0^{in}.001795\,\Delta$$

so that we have for the mean expansion of the 15 feet brass bar between 32° and 89°.15 F.

$$e = 0^{in}.001795\,(1 - \Delta) \pm 0^{in}.0000016.$$

§ 14. In May, 1876, an additional determination of the expansion of the 15 feet brass bar for 1° F. was made, using a temperature range from 32° to 65° F.

The end surfaces of the steel pins in the ends of the iron bar having become slightly rusty they were polished off, thus making the iron bar shorter than in the preceding expansion-work.

The following table gives the results of the comparisons between the iron 15 feet bar, always packed in ice, and the brass 15 feet bar, either packed in ice or heated to about 62°.

The same method and the same care was used as in the determinations previously made. The column I—B gives the observed excess of length of iron over brass bar:

Date.	Iron-bar temperature.	Brass-bar temperature.	I—B.	Residuals, compared —observed.
1876.	° *Fah.*	° *Fah.*	*Inches.*	
May 6	32. 00	32. 00	+0. 034373	—0. 000067
May 9	32. 00	65. 18	—0. 024697	—0. 000256
May 10	32. 00	32. 00	+0. 034298	+0. 000008
May 11	32. 00	61. 60	—0. 018595	+0. 000036
May 13, 12 m	32. 00	61. 04	—0. 0175 1	—0. 000058
May 13, 3 p. m	32. 00	61. 06	—0. 017499	—0. 000096
May 15, 3 p. m	32. 00	32. 00	+0. 034316	+0. 000010
May 15, 4 p. m	32. 00	32. 00	+0. 034282	—0. 000024
May 16, 3. 30 p. m	32. 00	61. 22	—0. 017945	+0. 000065
May 16, 4 p. m	32. 00	61. 00	—0. 017561	+0. 000073
May 16, 8. 20 p. m	32. 00	61. 45	—0. 018541	+0. 000250
May 17	32. 00	32. 00	+0. 034394	+0. 000068
May 18	32. 00	32. 00	+0. 034245	—0. 000061

Each observation gives an equation of condition of weight 1. Solving these by least squares, we have for mean expansion of 15 feet brass bar from 32° to 62° F. for 1° F.

$$e = 0^{\text{in}}.001786 \pm 0^{\text{in}}.0000015 - 0.001786\ \Delta.$$

This value is identical with that derived from the Clarke yards, through the brass yards § 9, except that its probable error is much less.

The discrepancy, amounting to $\frac{1}{187}$ part of the whole value, between this and the value $0^{\text{in}}.001795$, obtained for the mean expansion between 32° and 89°.15, may be accounted for in three ways:

1st. It may be attributed solely to errors of observation, and the work would still be good, as the discrepancy is small.

2d. The mean expansion of the 15 feet bar may be greater between 32° and 89° than between 32° and 62°. Working on small specimens, Fizeau has found for the expansion of a unit's length of brass for t centigrade degrees—

$$(1034 \times 10^{-8})\, t^{\circ} + (76 \times 10^{-10})\, t^{\circ 2}$$

the expansion depending on both t and t^2.

3d. If thermometer 21472 should have a very small systematic position, correction at 62° to reduce it to an air-thermometer and one of $+0^{\circ}.3$ at 89°, the two expansions would agree.

The length of the 15 feet brass bar at 62° has already been given. As it was compared with the brass yards Nos. 6, 7, 8, 9, 10, at 62° on three days, as these yards were compared with each other and the Clarke yards at temperatures between 54° and 63°, and as the Clarke yards were compared with the Ordnance Survey standard between 62° and 64°, any slight errors in the values of the relative or absolute expansions can have little effect on the resulting length of the 15 feet bar at 62°. But as the Keweenaw, Sandy Creek, and Buffalo bases depend on the length of this bar packed in melting ice, the question arises how its length at 32° should be derived from the data already given.

1st. Using the expansions of the Clarke yards given by Colonel Clarke, their lengths at or near 32° can be derived from their comparisons with the Ordnance Survey standard at temperatures between 51° and 64° F. The Clarke yards, the brass yards, Nos. 6, 7, 8, 9, 10, and the 15 feet brass bar have been intercompared at temperatures between 33° F. and 44°.

Hence the length of the 15 feet brass bar at 32° F. can be obtained without using any expansions, except those of the Clarke yards, over a range sufficient to introduce much error.

2d. The length of the 15 feet brass bar at 32° may be derived from the length adopted at 62° by using the mean expansion from 32° to 89°.15 F. already given, namely, $0^{\text{in}}.001795$.

3d. The length of the 15 feet brass bar at 32° F. may be derived from its adopted length at 62° by using the mean expansion from 32° to 62° F. for 1° already given, namely, $0^{\text{in}}.001786$.

In view of the probability that the expansion of the brass bar increases with the temperature, and of the fact that the expansion derived from the Clarke yards agrees with that obtained directly from expansion-experiment between 32° and 62°, it is deemed advisable to adopt for the present for the length of the 15 feet brass bar at 32° the value obtained by the first method, namely:

$$15 \text{ feet brass bar at } 32^{\circ} = 179^{\text{in}}.95438 \pm 0.000120 - 0.02198\ \Delta.$$

The probable error is derived from the probable error in the length of the bar at 62°, and from the probable error in the value of the expansion from 32° to 62°, directly determined.

This same value would result from the adopted length at 62°, namely,

$$180^{\text{in}}.00796 \pm 0.000111 - 0.02198\ \Delta.$$

if the mean expansion between 32° and 62°, directly obtained, namely, $0^{\text{in}}.001786$, were used. If the mean expansion between 32° and 89°, directly obtained, had been used it would have made the length of the 15 feet brass bar at 32° $\frac{1}{660000}$ less.

The results obtained for the 15 feet brass bar up to May, 1877, may now be given:

Length of 15 feet brass bar at 62° F. $= 180^{\text{in}}.00796 \pm 0.000111 - 0.02198\ \Delta$.
Length of 15 feet brass bar at 32° F. $= 179^{\text{in}}.95438 \pm 0.000120 + 0.03160\ \Delta$.
Mean expansion between 32° and 89° for 1° F. $= 0^{\text{in}}.001795 \pm 0.0000016 - 0.001795\ \Delta$.
Mean expansion between 32° and 62° F. $= 0^{\text{in}}.001787 \pm 0.0000015 - 0.001786\ \Delta$.

§ 15. Much of the work of which a summary has now been given has been done by Assistant Engineers E. S. Wheeler, G. A. Marr, T. Russell, and C. Pratt.

Mr. Wheeler has made a large part of the observations, and great credit is due him for his constant endeavors to increase the accuracy of the work. Fertile in resources, his aid has been of especial value in working out details of apparatus and comparisons.

C. B. COMSTOCK.

APPENDIX B.—LENGTH OF KEWEENAW BASE.

1. In the Lake-Survey Report for 1874 a preliminary length of the Keweenaw base was given, based on a preliminary value of the length of the 15-feet brass bar of the Lake Survey, when packed in melting ice, then taken as $179^{in}.95752$.

The length of the base obtained was 1933 (15-feet bar in melting ice) $+ 47^{in}.71$.

It was then known that the tubes changed length during the day by considerable quantities when the temperature changed rapidly, but even an approximation to a law connecting length-changes with temperature-changes was unknown.

Since 1873 the comparisons of tubes with standard bar continuously during the day at Sandy Creek and Buffalo bases have given empirically such a law, and have led to a recomputation of the Keweenaw base.

2. In a compensated base apparatus like the Bache-Würdemann, (described in the Coast Survey Report, 1854,) the length of a tube may change from a change of temperature in two ways:

1st. Its length may change from the unequal expansion of the brass and iron bars, when their changing temperatures are constantly equal to each other, this change of length arising from incorrect proportions in the compensating lever. This change in length from imperfect compensation is called expansion. It can be reduced to almost zero, and has been made very small in the Lake Survey apparatus.

2d. In changing temperatures the bars may not gain or lose heat alike, and the length of the tube may change from the difference in their temperatures. This is the serious difficulty in any apparatus composed of two bars, whether in the form of a compensating apparatus, like the Colby and the Bache-Würdemann, or in the form of a metallic thermometer like the apparatus of Borda, of Bessel, and of Repsold. The problem of keeping the two bars at the same temperature is not well solved in the compensating apparatus of the Lake Survey, and any such apparatus has the great disadvantage of giving exaggerated changes of length for any difference in temperature between the two bars. Thus a compensated arrangement of brass and iron bars whose expansions for 1° are b and i, will change length for a difference of 1° in temperature of its two bars, by $\frac{b}{b-i}\,i$, or by about three times the change of length of the iron bar for 1° of temperature.

Some results from comparisons will be of interest as showing the amount of such changes in the Lake Survey base apparatus.

On August 5, 1873, during comparisons of tube 1, in full sunshine, the temperature of the interior of the tube rose from 60° at 6 a. m. to 98° F. at 5 p. m. The tube reached its maximum length at 9 a. m., and then decreased so as to be $0^{in}.00470$ shorter at 10 p. m. The day was one of excessive temperature range; such change of length approaches zero when the rate of temperature change during the day becomes very small. At the Buffalo base in 1875, the mean length of this tube for the 11 days of comparisons was at 1 p. m. $0^{in}.00230$ greater than at 8 a. m., the comparisons being under tents.

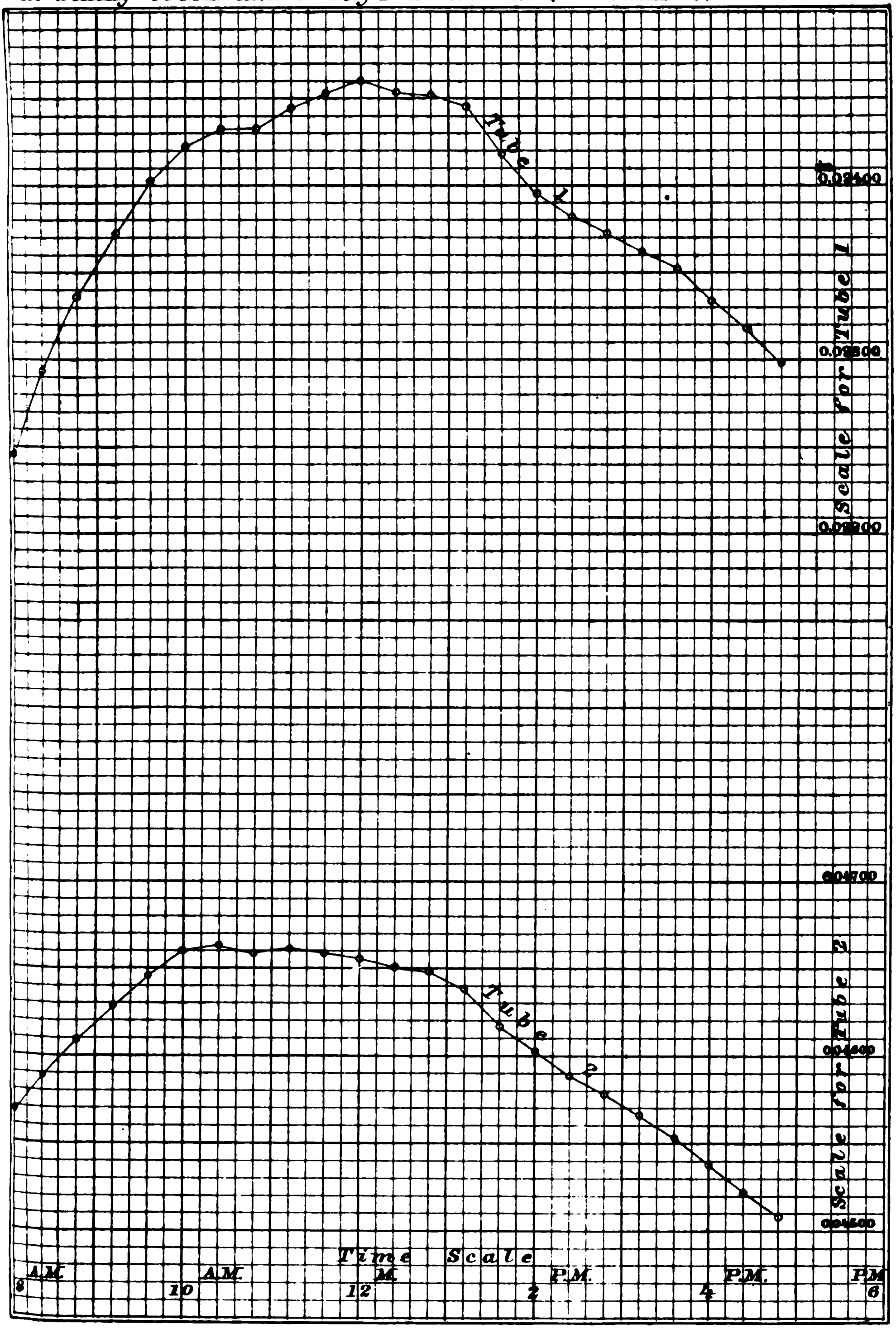
The variation for tube 2 was less.

But as a part of this change might be due to expansion of tube from imperfect compensation, while the two bars have equal but varying temperatures, that question has been re-examined. Two attempts had been made in the office at the determinations of the expansions of the tubes, and the comparisons at the base-lines also gave data; but the quantity to be measured is so small, and is so masked by larger errors, that its determination is difficult. A combination of the various values gave for both tubes an expansion less than $0^{in}.00001$ for 1° F., and less than the probable error of the determination. Hence, in the recomputation of the base, the expansions for both tubes have been taken as zero. As the mean temperatures of the tubes during comparisons and during measurement of the Keweenaw base did not differ by more than 1° F., the uncertainty in the precise values of the expansion does not affect their lengths by more than $0^{in}.00001$, a quantity which may be neglected.

The fact that the tubes change length during the day being known, and it also being known that their proper expansion (both bars having the same temperatures) is very small, it follows that the change in length given above must be due to difference of temperature of the two bars. When tube 1, on August 5, 1873, changed length during the day by $0^{in}.00470$, taking one-third of this quantity as giving the change of the length of the iron bar relatively to the brass bar, we find that the temperatures of the iron bar relatively to the brass bar must have changed by about 1°. 3 F. during the day, and that on an average comparison day at the Buffalo base the relative temperature of iron and brass bars must have varied by 0°.7 F.

3. The variations in length of tubes 1 and 2 during comparisons under tents are well shown graphically by the following curves, in which the abscissas give the hours of the day and the ordinates the corresponding excess of the length of the tube above that of the 15-feet brass bar, in melting ice. The curves for tubes 1 and 2 are each

Mean curves of Tubes 1 and 2 during 12 days of comparisons at Sandy Creek and 11 days at Buffalo, 1874 and 1875.



the means of daily comparison-curves for 23 days of comparisons at Sandy Creek and Buffalo bases. From these curves it will be seen that for an average day during comparisons at those bases tube 1 changed length between 8 a. m. and 5 p. m. by $0^{in}.00216$, and tube 2 by $0^{in}.00154$, these changes being due almost entirely to difference of temperatures of the brass and iron bars in each tube.

4. In the computation of the Keweenaw base in 1874 the lengths adopted for the tubes during measurement were derived from comparisons of the tubes with the bar in melting ice, the tubes being under a tent, as in measurements, and the comparisons being repeated at short intervals during the working-day. The differences of lengths of bar and tube were plotted for each day as ordinates, the hours of the day being the abscissas, so that for each day of comparison a curve resembling those already given was obtained. The mean ordinate for the day was computed, giving the tubes mean length for that day. The mean of such mean lengths for the periods of comparisons gave the length of the tube in terms of the bar in ice, which was used in computation.

If the mean daily temperature-curve during comparisons had precisely the same form and dimensions as during measurements, thus giving the same mean curve for the daily changes of length of tube during comparisons and measurement, no error would be introduced into the resulting length of the whole base, although these mean values would not give the same length in remeasurement for a part of the base, for which the temperature-curves on the two days of measurement differed considerably.

In fact, the mean temperature range between 8 a. m. and 12 m. on the days of comparison was 6°.1 F., while on the days of measurement it was 13°.2, a difference too great not to need a correction if any method can be found for making it.

5. The numerous comparisons of the base-tubes with the 15 feet brass bar in ice at Sandy Creek and Buffalo bases added largely to our knowledge of the conduct of the tubes during rapidly-changing temperatures, and showed what had previously been noticed, that the mean daily length of a tube depended on the temperature range during the morning.

After some trials it was found if the mean daily differences of length of tube and bar in ice were plotted as ordinates, the temperature changes from 8 a. m. to 12 m. being the abscissas, that the resulting curve was nearly a straight line for the Keweenaw, Sandy Creek, and Buffalo bases, and that for each base the slope of the line was nearly the same.

That is, if we represent by l the difference of lengths of 15 feet bar in ice and tube, when its iron and brass bars have the same temperature; by x the change in the mean difference between 8 a. m. and 5 p. m. due to a change of temperature of 1° F. between 8 a. m. and 12 m.; by a the change of temperature from 8 a. m. to 12 m. on any day when the mean difference of length between 8 a. m. and 5 p. m. of bar in ice, and tube is d; we shall have—

$$l+ax=d$$

l is constant so long as no permanent change in the length of the tube takes place. As already stated, the expansion of the tube, both bars being always at like temperatures, is so small and uncertain as to be neglected; if it had a definite value it would also be necessary to fix a temperature for the normal length.

The above equation expresses in effect that the mean length of a tube between 8 a. m. and 5 p. m. on any day is equal to its normal length plus the temperature change from 8 to 12 a. m., multiplied by a constant.

Each day of comparisons continued from 8 a. m. to 5 p. m. of a tube under tent with the bar in ice on Keweenaw, Sandy Creek, or Buffalo bases gives an equation of condition of the above form. The value of x will be the same in all; the value of l will be the same so long as there is no evidence of a permanent change in its value. Such change occurs between the measurement of different bases, and sometimes during the measurement of the same base.

6. This liability to change in length is a serious evil in the Bache-Würdemann apparatus. There are in it thirteen joints or points of contact, at any one of which change in contact by wear or by change of adjustment may change the length of the tube. As in consequence of jars and expansions the screws on which these joints depend frequently get loose, these permanent changes in length are unavoidable, and they are large enough to seriously diminish the accuracy of the work unless much time is spent on comparisons, which would otherwise be unnecessary. In any base apparatus it is very much to be desired that the points which fix the length of the apparatus should be rigidly connected with each other, or if there are joints that these should be very few in number and practically unchangeable.

In one of the tubes of the Lake Survey base apparatus the length of the tube can be changed by 0.003 inch, by simply tightening or loosening the screw which forms the axis of rotation of the compensating lever, the tightening twisting the le v original plane of rotation.

7. Having obtained from the comparisons at Keweenaw, Sandy Creek, and Buffalo bases twenty-eight equations of condition of the form $l+ax=d$ for each tube, these

equations contained for tube 1 a single value of l for Keweenaw base, and three values for each of the other bases, x being the same for all; while for tube 2 a single value for l was used for each base, x being the same for all.

For the Keweenaw base there was no evidence of change of length of either tube during the comparisons used. But on the Sandy Creek and Buffalo bases, while there was no evidence of change in length of tube No. 2 during the measurement of the base, there was evidence that tube No. 1 on both bases changed length between the comparisons at beginning and middle of measurement, and between the middle and end comparisons, necessitating the assumption of different lengths at each of the three periods of comparison at each base. Solving for each tube by least squares the 28 equations of condition resulting from 25 days' comparisons, the values of l and x are found.

The following are the values for l and x for the two tubes, with the dates of the comparisons on which they depend:

Tube 1.

Keweenaw base...... $l_1 = 0^{in}.01701 \pm 0^{in}.00012$, August 4–October 2, 1873.

Sandy Creek base.. $l_2 = 0^{in}.01905 \pm 0^{in}.00015$, August 13–19, 1874.
$l_3 = 0^{in}.01777 \pm 0^{in}.00016$, September 15–17, 1874.
$l_4 = 0^{in}.01727 \pm 0^{in}.00017$, October 17–23, 1874.

Buffalo base........ $l_5 = 0^{in}.02726 \pm 0^{in}.00017$, August 31–September 3, 1875.
$l_6 = 0^{in}.02682 \pm 0^{in}.00021$, September 22–23, 1875.
$l_7 = 0^{in}.02591 \pm 0^{in}.00016$, October 11–14, 1875.

For tube 1, $x = 0^{in}.000136 \pm 0^{in}.000009$.

Tube 2.

Keweenaw base.... $l'_1 = 0^{in}.043135 \pm 0^{in}.00014$, July 17–23, 1873.
Sandy Creek base.. $l'_2 = 0^{in}.04406 \pm 0^{in}.00011$, August 13–October 23, 1874.
Buffalo base........ $l'_3 = 0^{in}.04598 \pm 0^{in}.00012$, August 28–October 14, 1875.

For tube 2, $x = 0^{in}.000097 \pm 0^{in}.000008$.

8. The following diagrams show how closely these values of l and x represent the results of comparisons for each tube and each base. Abscissas are the changes of temperature of tube between 8 and 12 a. m. on a comparison day, and the ordinates of the points inclosed by a circle with a date are the excesses of the mean tube length on that comparison day over that of the 15-feet bar in melting ice. Where tube 1 changed length during measurement, these ordinates have been corrected so as to free them from the effect of that change, and to make them give only the temperature effect.

The straight line is plotted from the first values for each base of the tube's normal length and from the values of x just given. The distances of the points from the right line are due to the errors of observation and of theory, and for the apparatus in question must be considered as reasonably small.

9. The method followed in the recomputation of the Keweenaw base can now be explained.

The computations for the corrections to measured length, for inclination of tubes, for contact-level, for error in sector-level adjustment, and for error in cylindrical surface, are the same as heretofore. But in the computation of 1874 a mean length of Tube 1 was adopted for all the days of measurement without attempting to take into account the effect of the daily temperature-range on the tube's length.

In recomputation, the value of the excess l, of the normal length of tube 1 over bar in ice for Keweenaw base, already given, namely, $0^{in}.01701$, was used for the whole base. For each full day of measurement (from 8 a. m. to 5 p. m.) the temperature-change a, from 8 a. m. to 12 m., was taken from the thermometer-readings inside of the tube, and this, with the proper value of x previously given, enabled us to compute $l + ax$, the excess of the mean length of the tube for that day over the bar in ice. The mean length multiplied by the number of times that tube was used during the day, gave the length measured by it.

When measurements were made on any day during a fraction of the period from 8 a. m. to 5 p. m., the mean length of the tube during the fraction of a day would usually differ from the mean length for the whole day, and hence the computed value $l + ax$ would need a correction to give the mean length of the tube while being used.

To obtain this correction the mean curve of § 8, giving the average daily variations of the tube's length at Sandy Creek and Buffalo bases, was used. The difference between the mean ordinates of this curve for the whole day and for the fraction of the day during which measurements were made was applied to the computed value $l + ax$ as a correction, and the result was used to obtain mean length for the fraction of a day. The same method was followed in computing the mean length of tube 2 for

each day or fraction of a day of measurement. But the normal length of this tube changed permanently during the measurement, as described in the Lake Survey Report for 1874. For the half of the base measured prior to September 11, 1873, the value l'_n previously given, resulting from the least-square reductions, of the comparisons, was used, namely, $l'_n=0^{\text{in}}.043135$.

The comparisons on September 30 and October 1, 1873, after the measurement of the base, using the value of x already obtained, give $l=0^{\text{in}}.03985$. Hence, from September 11 to September 30, the mean of the above values is used, and after October 1, in the remeasurements the last value, $0^{\text{in}}.03985$, is used.

10. As a part of the Keweenaw base equal to 94 tube-lengths (about 1,410 feet) was remeasured seven times, a recomputation of these parts by the new method and a comparison of the results give a new value for the probable error of measurement, so far as it can be derived from a comparison of single measures with their mean.

The seventh remeasurement is not included, as it is nearly certain from comparison with the other measurements that an error of either 1° or 2° was made at one point in reading the angle of inclination of the tube.

The following table gives the number of the measure, its date, the maximum and minimum tube-temperature during the measurement, and the excess of the separate measures over their mean.

Number.	Date.	Temperature. Max.	Temperature. Min.	Excess.
		°	°	*In.*
1	August 16, 18, 19, 1873	82.2	66.6	+0.075
2	August 20, 1873	71.1	66.0	−0.008
3	August 21, 22, 1873	81.8	62.7	−0.003
4	August 23, 1873	65.6	54.5	−0.041
5	October 6, 7, 1873	58.5	38.6	−0.045
6	October 7, 8, 1873	71.2	40.0	+0.022

Deducing from these residuals the probable error of one measurement, it is found $0^{\text{in}}.030$, or about $\frac{1}{160000}$.

It will be noticed that while on some days the whole distance was measured, for other measurements two, or even three, days were required. As this involved the difficult estimate of the mean tube-length for parts of days by the approximate method already described, it seems probable that the errors in these remeasurements are larger than in the continuous measurement of the base, when there were relatively fewer fractional days of measurement.

11. In attempting to obtain a value for the probable error in the measurement of the base, the first question is as to the accuracy of the values of tube-lengths used in the computations. The probable errors in the values of l for tubes 1 and 2, as derived by the least-square reductions, are given in § 7 as $\pm 0^{\text{in}}.00012$ and $\pm 0^{\text{in}}.00014$ respectively. The corresponding probable errors in the values of x are $\pm 0^{\text{in}}.000009$ and $\pm 0^{\text{in}}.000008$. As the average temperature-range between 8 and 12 a. m. on days of measurement was $13^{\circ}.2$, the average probable errors in the values of ax would be $\pm 0^{\text{in}}.00012$ and $\pm 0^{\text{in}}.00010$ for the tubes 1 and 2.

Hence the probable error in the value of d for tube 1 would be, approximately,

$$\sqrt{(0.00012)^2+(0.00012)^2}=\pm 0^{\text{in}}.00017$$

and for tube 2, also,

$$\pm 0^{\text{in}}.00017.$$

As the length of the base was 1,933 tubes, these probable errors give for the whole base

$$1933\times\pm 0^{\text{in}}.00017=\pm 0^{\text{in}}.329.$$

Taking the estimates in the Lake-Survey Report for 1874 of the errors from other causes, we have for all—

1. From probable error in adopted excess of length of tube over 15-foot bar in ice,

$$=1933\times\pm 0^{\text{in}}.00017=\pm 0^{\text{in}}.329.$$

2. From probable error in inclinations, ± 0.103.
3. From probable error in references to and from ground, ± 0.059.
4. From probable error in contact displacement, ± 0.109.
5. From probable error from change of length of tube 2, ± 0.158.

Taking the square root of the sum of the squares of these quantities, we have for

the probable error in the length of base (error in length of standard 15-foot bar not included) $\pm 0^{in}.399$.

In § 10 the probable error in one measurement of 94 tubes was given as $0^{in}.03$. This probable error arises from the inaccuracy with which $a\,x$ expresses the daily temperature-effect on the tubes, and from the 2d, 3d, and 4th of the errors given above.

For the whole base we should have from these causes the probable error

$$\pm 0.03\sqrt{\frac{1933}{94}} = \pm 0^{in}.136$$

If this were combined with the probable errors from the other sources a somewhat smaller probable error would be found for the whole base than that given above.

But, in view of the uncertainty in estimating probable errors in complex cases, that all sources of error have been considered, and from the danger of constant errors, as well as from the liability of this apparatus to change length, I do not deem it advisable to assume a probable error, excluding that in the length of the 15-foot bar, less than that given in the report for 1874, namely: $\pm 0^{in}.693$.

The length of the Keweenaw base, resulting from the recomputation after applying a correction of $-11^{in}.02$ to reduce it to the sea-level, is

$$1933\ (\text{15-foot bar in melting ice}) + 49^{in}.73 \pm 0^{in}.696$$

Taking for the length of the 15-foot bar in melting ice the value given in the paper on Standards of Length of the Lake Survey Report for 1877, namely,

$$179^{in}.95433 \pm 0^{in}.00012 + 0.03160\,\Delta$$

we have for the length of the Keweenaw base

$$347901^{in}.55 \pm 0^{in}.734 + 61.0828\,\Delta$$

NOTE.—As a check on the parts of the base into which it was divided near its middle. the angles of two triangles having a common vertex, and the parts of the base for opposite sides, were read. Computing the north half of the base from the whole base, the computed length was $0^{in}.27$ greater than the measured length, or $\frac{1}{644000}$, while the computed south half was $1^{in}.16$ greater than the measured length, or $\frac{1}{150000}$. As the angles of this small triangulation were not carefully measured, the agreement is as good as was to be expected.

C. B. COMSTOCK.

APPENDIX C.—TELEGRAPHIC LONGITUDE.

REPORT OF CAPTAIN H. M. ADAMS, CORPS OF ENGINEERS, ON TELEGRAPHIC LONGITUDE WORK IN CONNECTION WITH THE LAKE SURVEY OBSERVATORY, 1876-'77.

The longitudes of the following points have been determined:

1. Mount Forest, Ill.
2. Saginaw, Mich.
3. Saint Louis, Mich.
4. Cairo, Ill.
5. Fort Fetterman, Wyo.
6. Fort Richardson, Tex.
7. Fort Griffin, Tex.
8. Fort Stockton, Tex.
9. Fort Concho, Tex.
10. Fort McKavett, Tex.

Observations were made at Detroit by Capt. H. M. Adams for all longitudes except Forts Richardson and Griffin. The following instruments were used: Transit instrument made by Buff & Berger. Focal length, 39 inches; magnifying power of telescope with diagonal eye-piece, 87; aperture, 3 inches. Clock No. 256, and chronograph No. 216, made by Bond & Sons.

For longitudes of Mount Forest, Saginaw, Saint Louis, and Cairo, signals were exchanged by automatic clock and chronometer beats; and for all other stations by breaking or making circuit by hand every ten seconds. All signals were recorded at Detroit on a chronograph. A complete time-determination was made before and after signals each night in determining the longitudes of the following points:

Mount Forest, Ill. (See Tables Nos. 3, 4, 5, and 6.)

Saginaw, Mich. (See Tables Nos. 13 and 14.)
Saint Louis, Mich. (See Tables Nos. 15 and 16.)
Cairo, Ill. (See Tables Nos. 17 and 18.)

In each time-determination, two stars of over 80° declination were observed, and the telescope was reversed on each so as to obtain seven wires before and after reversal. Five or more time stars were observed over fifteen wires for telescope direct, and the same number with telescope reversed.

PROGRAMME FOR TIME-DETERMINATION.

Level-readings.
A circumpolar star, (reversal on.)
Level-readings.
Five or more well-determined time-stars.
Level-readings.
Reversal.
Level-readings.
Five or more well-determined time-stars.
Level-readings.
A circumpolar star, (reversal on.)
Level-readings.

Level-readings were also taken between the time-stars when the interval of time was sufficient.

The time occupied for telegraphic signals was generally twenty minutes between the two independent time-determinations. In determining the longitudes of the following points, less extended observations for clock-correction were made at Detroit.

Fort Fetterman, Wyoming. (See Tables Nos. 9 and 10.)
Fort Stockton, Texas. (See Tables Nos. 8 and 9.)
Fort McKavett, Texas. (See Tables Nos. 6 and 12.)
Fort Concho, Texas. (See Table No. 11.)

For longitude of Forts Richardson and Griffin, observations were made at Detroit by Assistant Engineers O. B. Wheeler and A. R. Flint.

Observations were made for personal equation by Captain Adams and Lieutenant Lockwood in exactly the same manner as for determining longitude. The transit-instruments were mounted on piers five feet apart. Personal equation was determined on two nights in July, 1876, on one night in October, 1876, and on three nights in March, 1877, after completing the longitude-work at Cairo. The results are given in Tables Nos. 1, 2, 7, 19, 20, 21, 22, and 27.

COMPUTATIONS.

The time-work for all stations was computed by the method of high and low stars, and the time-work for longitude of Mount Forest, Ill., a primary triangulation station near south end of Lake Michigan, was also computed by the method of least squares. All computations have been checked or duplicated.

The probable errors of transit over a single thread were computed for stars of different declinations, as follows:

Table A.

	δ		ε
	°	′	s.
λ Ursæ Minoris	88	56	± 1.51
51 Cephei	87	14	0.63
δ Ursæ Minoris	86	37	0.46
32 Camelopardalis	84	05	0.50
Carrington 3525	83	41	0.41
Carrington 299	82	59	0.35
1 Draconis	81	52	0.33
Carrington 76	81	49	0.27
Stars of less than	10	dec.	0.066

For all time-stars a weight unity was given to the mean of eleven wires, and the table of weights below was then computed from the formula

$$p=\frac{\varepsilon_{,}^{2}+\frac{\varepsilon^{2}}{11}}{\varepsilon_{,}^{2}+\frac{\varepsilon^{2}}{n}}$$

p = the weight to be given to n wires.
$\varepsilon_{,}$ = the probable culmination error = ± 0s.049.
ε = the probable error for one wire = ± 0.066.

The above value for $\varepsilon_{,}$ = is that adopted for the larger instruments of the United States Coast Survey. (See page 224, Report of 1872.)

Table B.

Number of wires.	p.	Number of wires.	p.
5	0.86	12	1.01
6	0.89	13	1.02
7	0.93	14	1.03
8	0.95	15	1.04
9	0.97	16	1.05
10	0.99	17	1.05
11	1.00	18	1.06

The weights given to high stars were computed from the formula

$$p' = \frac{p\,\varepsilon^2}{\varepsilon'^2}$$

ε' = the probable error for one wire for a high star.
p' = the weight to be given to n wires.
The value of p is given in Table B: ε, and ε' in Table A.

After completing the computation of seven nights' work by the method of least squares, a comparison was made with the preliminary reduction by the method of high and low stars. The greatest differences in results from the two methods of computation were, for clock-correction, $0^s.033$; for clock-rate per hour, $0^s.014$. The mean differences were, for clock-correction, $0^s.015$; for clock-rate per hour, $0^s.005$.

The right ascensions were determined from American Ephemeris, 1876–'77; German Catalogue, 539 Sterne, 1876–'77, and General Bericht Europäische Gradmessung, 1873.

RESULTS.

Longitudes are reckoned from east pier of Lake Survey Observatory, 1876.

	m. s.
Astronomical station at Mount Forest, Ill., west	19 15.315
A mean of four results. (See Table No. 23.)	
Astronomical station at Saginaw, Mich., west	3 38.966
A mean of two results. (See Table No. 24.)	
Astronomical station at Saint Louis, Mich., west	6 12.575
A mean of two results. (See Table No. 25.)	
Astronomical station at Cairo, Ill., west	24 25.866
A mean of two results. (See Table No. 26.)	

The observations at Mount Forest, Saginaw, Saint Louis, and Cairo were made by Lieut. D. W. Lockwood, United States Engineers. Tables of time-work are given in his report, Appendix D.

Fort Fetterman, Wyoming:	h. m. s.
From work of July 22, 1876, west	1 29 45.50
From work of July 28, 1876, west	1 29 43.65
Mean west	1 29 44.6

Time observations were made at Fort Fetterman by Capt. W. L. Stanton, with a sextant. Results given in office papers 6?0 and 736.

Fort Richardson, Texas:	h. m. s.
From work of May 10, 1876, west	1 00 26.55
From work of May 12, 1876, west	1 00 26.48
Mean west	1 00 26.51

Fort Griffin, Texas:	h. m. s.
From work of June 5, 1876, west	1 04 43.21
From work of June 6, 1876, west	1 04 42.84
Mean west	1 04 43.02

For June 5 the clock-correction at Detroit depends on observations made June 2 and 6.

Fort Stockton, Texas:	h. m. s.
From work of July 17, 1876, west	1 19 18.08
From work of July 22, 1876, west	1 19 16.98
Mean west	1 19 17.53

Fort Concho, Texas:	h. m. s.
From work of July 31, 1876, west	1 09 30.64

Fort McKavett, Texas:	h. m. s.
From work of August 29, 1876, west	1 08 13.28

The clock-correction at Detroit depends on observations of August 26 and September 1.

Observations at Forts Richardson, Griffin, Stockton, Concho, and McKavett were made by Lieut. William Hoffman, Eleventh United States Infantry, acting engineer officer Department of Texas, and the longitudes of the above points depend on the time of signals sent and received at these places, as furnished by Lieutenant Hoffman in office report No. 797.

A large discrepancy, $1^s.1$, appears in the results for two nights' work at Fort Stockton. All computations of time-work and time of signals at the Lake Survey Observatory have been duplicated and checked.

EXPLANATION OF TABLES.

I.—*Tables 1 to 7, inclusive.*

Computation of time-determinations by the method of least squares "D" indicates telescope direct; "R" indicates telescope reversed.

a = the assumed value for azimuth of transit-instrument in seconds of time.
δa = the correction to a determined from normal equations.
A = the azimuth factor.
B = the inclination factor.
C = the collimation factor.
b = the level-correction.
c = the correction for collimation.
Δi = the reduction to the middle wire.
$a\,b\,r$ = the correction for diurnal aberration $= 0^s.021$ cos. latitude.
r = the interval in clock-hours for which the rate ρ is applied.
ρ = the rate per clock-hour $\left\{\begin{array}{l}+ \text{ when losing.}\\ - \text{ when gaining.}\end{array}\right.$
t' = the observed time of transit corrected for azimuth, inclination, collimation, reduction to middle wire, diurnal aberration, and rate.
α = the right ascension.
$\Delta t'$ = the clock-correction at a given epoch as determined from a single star.
p = the weight given to $\Delta t'$.
θ = the assumed value for clock-correction at a given epoch.
$\delta\theta$ = the correction to θ determined from normal equations.
Δt_0 = the clock-correction at a given epoch $= (\theta + \delta\theta) \left\{\begin{array}{l}+ \text{ when slow.}\\ - \text{ when fast.}\end{array}\right.$

II.—*Tables 8 to 21, inclusive.*

Computation of time-determinations by the method of high and low stars:

t_0 = the observed time of transit corrected for azimuth, inclination, collimation, reduction to middle wire, and diurnal aberration.
Δt = the clock-correction from a single time-star.
$\Delta t' = \Delta t$ corrected for rate.
a = the azimuth of transit-instrument as computed from high and low stars.
Other symbols denote the same as in computation by least squares.

III.—*Tables 22 to 27, inclusive.*

Telegraphic comparisons of time-pieces for determination of longitude and for personal equation of observers.

Each result is the mean from 15 ticks as registered by both time-pieces on a chronograph.

The chronograph-readings for a single result from fifteen ticks sent from Cairo to Detroit are given below:

	CAIRO. Chronometer No. 1524.			DETROIT. Clock No. 256.		
	h.	*m.*	*s.*	*h.*	*m.*	*s.*
	4	26	07.00	4	28	05.30
	4	26	08.00	4	28	06.30
	4	26	09.00	4	28	07.30
	4	26	10.00	4	28	08.30
	4	26	11.00	4	28	09.30
	4	26	12.00	4	28	10.30
	4	26	13.00	4	28	11.30
	4	26	14.00	4	28	12.30
	4	26	15.00	4	28	13.30
	4	26	16.00	4	28	14.30
	4	26	17.00	4	28	15.31
	4	26	18.00	4	28	16.30
	4	26	19.00	4	28	17.30
	4	26	20.00	4	28	18.30
	4	26	21.00	4	28	19.30
Means	4	26	14.000	4	28	12.301

All comparisons of time-pieces for longitude of Mount Forest, Saginaw, Saint Louis and Cairo were made as above.

TABLE 1.—*Detroit, July 15, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	$A(a+\delta a)$	Bb	$C(c+\Delta i+abr)$	$r\rho$	t'	a	$\Delta t'$	p
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
	Carr. 580, (L. C)	+ 1.20	....	....	+0.02	16 01 14.11	3 59 37.21	−1 36.90	0.027
R.	ε Ophiuchi	+ 0.12	−0.03	−0.27	+0.02	16 13 24.92	16 11 48.41	−1 36.51	1.
R.	γ Herculis	+ 0.07	−0.03	−0.29	+0.02	16 18 06.14	16 16 29.63	−1 36.51	1.
R.	ω Herculis	+ 0.08	−0.02	−0.28	+0.02	16 21 20.84	16 19 44.17	−1 36.67	1.
R.	β Herculis	+ 0.06	−0.02	−0.30	+0.02	16 26 32.58	16 24 56.04	−1 36.54	1.
R.	ζ Herculis	+ 0.04	0.00	−0.32	+0.01	16 38 15.55	16 36 39.42	−1 36.13	1.
D.	49 Herculis	+ 0.08	+0.02	+0.25	+0.01	16 48 05.33	16 46 28.87	−1 36.46	1.
D.	κ Ophiuchi	+ 0.09	+0.02	+0.25	+0.01	16 53 27.18	16 51 50.69	−1 36.49	1.
D.	ε Herculis	+ 0.04	+0.02	+0.29	+0.01	16 57 11.82	16 55 35.46	−1 36.36	1.
D.	d Herculis	+ 0.03	+0.02	+0.29	+0.01	16 58 40.78	16 57 04.24	−1 36.54	1.
D.	60 Herculis	+ 0.08	+0.01	+0.25	+0.01	17 01 16.91	16 59 40.52	−1 36.39	1.
D.	Groom. 2415	+ 0.01	+0.01	+0.32	+0.01	17 05 23.17	17 03 46.57	−1 36.60	1.
	Carr. 770, (L. C)	+ 1.56	....	....	0.00	17 23 59.74	5 22 23.34	−1 36.40	0.020
R.	51 Cephei, (L. C)	+ 2.67	+0.46	....	−0.02	18 43 13.28	6 41 37.50	−1 35.78	0.011
		$A(a'+\delta a')$							
D.	51 Cephei, (L. C)	+18.55	+0.62	....	−0.02	18 43 14.12	6 41 37.50	−1 36.62	0.010
D.	ζ Aquilæ	+ 0.57	−0.05	+0.25	−0.02	19 01 22.02	18 59 45.55	−1 36.47	1.
D.	ι Lyræ	+ 0.16	−0.07	+0.30	−0.02	19 04 31.81	19 02 55.45	−1 36.36	1.
D.	ω Aquilæ	+ 0.61	−0.06	+0.25	−0.02	19 13 39.21	19 12 02.76	−1 36.45	1.
D.	δ Aquilæ	+ 0.74	−0.06	+0.24	−0.02	19 20 54.38	19 19 17.86	−1 36.52	1.
D.	β Cygni	+ 0.33	−0.13	+0.24	−0.03	19 27 22.41	19 25 46.12	−1 36.29	1.
R.	γ Aquilæ	+ 0.63	−0.08	−0.28	−0.03	19 42 01.41	19 40 24.88	−1 36.53	1.
R.	α Aquilæ	+ 0.65	−0.09	−0.28	−0.03	19 46 23.46	19 44 47.03	−1 36.43	1.
R.	η Aquilæ	+ 0.77	−0.08	−0.27	−0.03	19 47 49.14	19 46 12.51	−1 36.63	1.
R.	β Aquilæ	+ 0.69	−0.09	−0.28	−0.03	19 50 52.96	19 49 16.38	−1 36.58	1.
R.	γ Sagittæ	+ 0.48	−0.12	−0.29	−0.03	19 54 53.92	19 53 17.47	−1 36.45	1.
	Carr. 3091	− 7.62	....	....	−0.04	20 18 56.83	20 17 19.58	−1 37.25	0.020
	76 Draconis	− 5.38	....	....	−0.05	20 53 07.45	20 51 30.86	−1 36.59	0.042

From Carr. 580, $c = +0.247$, tels. direct.
From Carr. 770, $c = +0.178$, tels. direct.
From Carr. 3091, $c = +0.235$, tels. direct.
From 76 Draconis, $c = +0.224$, tels. direct.

Mean....... $c = \pm 0.221$ { tels. direct. / tels. reversed.

$a = +0.16$

$a' = +1.21$

$c + \Delta i + abr = +0.244$. tels. direct.

$c + \Delta i + abr = -0.277$. tels. reversed.

$\theta = -1^m\ 36^s.5$ at $17^h\ 38^m$ clock-time.

Normal equations.

$$+21.130\,\delta\theta + 4.740\,\delta a + 4.684\,\delta a' - 8.720\,\rho = +0.230$$
$$+4.740\qquad +7.916\qquad 0.000\qquad +4.411\qquad = +0.243$$
$$+4.684\qquad 0.000\qquad +6.959\qquad -8.532\qquad = -0.341$$
$$+8.720\qquad +4.411\qquad -8.532\qquad +47.711\qquad = +0.909$$

$\delta\theta = +0^s.026 \quad \delta a = +0^s.007 \quad \delta a' = -0^s.049 \quad \rho = -0^s.014$

$\Delta t_0 = -1^m\ 36^s.474$ at $17^h\ 38^m$ clock-time.

TABLE 2.—*Detroit, July 18, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	A $(a+\delta a)$	Bb	C$(c+\Delta i+abr)$	$r\rho$	t'	a	$\Delta t'$	p
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
	Carr. 580, (L. C.)	+ 8.18			+0.03	16 01 16.18	3 59 37.81	−1 38.37	0.026
R.	ε Ophiuchi	+ 0.83	+0.05	− 0.25	+0.03	16 13 26.44	16 11 48.40	−1 38.04	1.
R.	γ Herculis	+ 0.47	+0.06	− 0.26	+0.02	16 18 07.68	16 16 29.61	−1 38.07	1.
R.	ω Herculis	+ 0.55	+0.06	− 0.25	+0.02	16 21 22.27	16 19 44.15	−1 38.12	1.
R.	β Herculis	+ 0.43	+0.06	− 0.27	+0.02	16 26 33.99	16 24 56.02	−1 37.97	1.
R.	ζ Ophiuchi	+ 0.92	+0.02	− 0.25	+0.02	16 32 00.80	16 30 22.82	−1 37.98	1.
D.	ξ Herculis	+ 0.25	+0.10	+ 0.25	+0.02	16 38 17.14	16 36 39.39	−1 37.75	1.
D.	η Herculis	+ 0.08	+0.11	+ 0.28	+0.02	16 40 19.27	16 38 41.36	−1 37.91	1.
D.	ε Herculis	+ 0.26	+0.09	+ 0.25	+0.01	16 57 13.31	16 55 35.44	−1 37.87	1.
D.	d Herculis	+ 0.20	+0.09	+16.48	+0.01	16 58 42.32	16 57 04.21	−1 38.11	0.855
D.	Groom. 2415	+ 0.04	+0.10	+ 0.29	+0.01	17 05 24.67	17 03 46.54	−1 38.13	1.
	Carr. 770, (L. C.)	+10.68			0.00	17 24 02.06	5 22 23.98	−1 38.08	0.020
	δ Ursæ Minoris	−13.49			−0.01	18 14 07.16	18 12 28.61	−1 38.55	0.022
D.	α Lyræ	+ 0.09	−0.01	+ 0.28	−0.02	18 34 25.15	18 32 47.22	−1 37.93	1.
D.	110 Herculis	+ 0.45	0.00	+ 0.23	−0.02	18 41 00.40	18 40 22.52	−1 37.88	1.
D.	β Lyræ	+ 0.22	+0.01	+ 0.26	−0.02	18 47 10.91	18 45 32.93	−1 37.98	1.
D.	θ' Serpentis	+ 0.71	+0.01	+ 0.22	−0.02	18 51 44.32	18 50 06.32	−1 38.00	1.
D.	ε Aquilæ	+ 0.55	+0.02	+ 0.22	−0.02	18 55 40.61	18 54 02.66	−1 37.95	1.
R.	ζ Aquilæ	+ 0.56	0.00	− 0.25	−0.02	19 01 23.66	18 59 45.56	−1 38.10	1.
R.	ω Aquilæ	+ 0.60	+0.03	− 0.25	−0.03	19 13 40.90	19 12 02.77	−1 38.13	1.
R.	δ Aquilæ	+ 0.73	+0.02	− 0.25	−0.03	19 20 55.96	19 19 17.88	−1 38.08	1.
R.	β Cygni	+ 0.33	+0.02	− 0.28	−0.03	19 27 24.00	19 25 46.14	−1 37.86	1.
R.	κ Aquilæ	+ 0.88	+0.01	− 0.25	−0.03	19 31 54.52	19 30 16.50	−1 38.02	1.
	λ Ursæ Minoris	−44.58			−0.04	19 51 16.50	19 48 37.64	−1 38.86	0.002

From Carr. 580, $c = +\ 0^s.186$, tels. direct.
From Carr. 770, $c = +\ 0^s.202$, tels. direct.
From δ Ursæ Minoris, $c = +\ 0^s.199$, tels. direct.
From λ Ursæ Minoris, $c = +\ 0^s.187$, tels. direct.

Mean...... $c = \pm\ 0^s.193$, $\left\{\begin{array}{l}\text{tels. direct.}\\ \text{tels. reversed.}\end{array}\right.$

$a = +\ 1^s.15$

$c+\Delta i+abr = +\ 0^s.216$, tels. direct.

$c+\Delta i+abr = -\ 0^s.246$, tels. reversed.

$\theta = -\ 1^m\ 38^s.0$ at $17^h\ 39^m$ clock-time.

Normal equations.

$$+19.925\,\delta\theta + 8.025\,\delta a - 3.690\,\rho = 0.000$$
$$+8.025 \quad +13.458 \quad -1.785 = -0.080$$
$$-3.690 \quad -1.785 \quad +31.928 = +0.554$$

$\delta\theta = +\ 0^s.006 \qquad \delta a = -\ 0^s.007 \qquad \rho = -\ 0^s.018$

$\Delta t_0 = -\ 1^m\ 37^s.994$ at $17^h\ 39^m$ clock-time.

TABLE 3.—*Detroit, August* 17, 1876.—*Observer, H. M. Adams.*

Tels.		Stars.	A a	B b	C (c+Δi+abr)	r ρ	t'	a	Δt'	p
			s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
	δ	Ursæ Minoris	+ 4.78			+0.04	18 14 11.20	18 12 19.61	—1 51.59	0.022
R.	1	Aquilæ	— 0.31	+0.00	—0.15	+0.03	18 30 22.25	18 28 30.70	—1 51.55	1.
R.	α	Lyræ	— 0.03	+0.00	—0.19	+0.03	18 34 38.33	18 32 46.93	—1 51.40	1.
R.	110	Herculis	— 0.15	+0.01	—0.16	+0.03	18 42 13.81	18 40 22.38	—1 51.43	1.
R.	β	Lyræ	— 0.07	+0.03	—0.17	+0.03	18 47 24.30	18 45 32.72	—1 51.58	1.
R.	θ'	Serpentis	— 0.23	+0.02	—0.14	+0.03	18 51 57.90	18 50 06.27	—1 51.63	1.
R.	ε	Aquilæ	— 0.18	+0.03	—0.15	+0.03	18 55 54.08	18 54 02.58	—1 51.50	1.
D.	ζ	Aquilæ	— 0.18	+0.07	+0.12	+0.03	19 01 37.09	18 59 45.50	—1 51.59	1.
D.	ι	Lyræ	— 0.05	+0.10	+0.14	+0.02	19 04 46.81	19 02 55.30	—1 51.51	1.
D.	ω	Aquilæ	— 0.19	+0.07	+0.12	+0.02	19 13 54.30	19 12 02.75	—1 51.55	1.
D.	δ	Aquilæ	— 0.23	+0.06	+0.12	+0.02	19 21 09.37	19 19 17.90	—1 51.47	1.
D	β	Cygni	— 0.10	+0.06	+0.13	+0.02	19 27 37.55	19 25 46.08	—1 51.47	1.
D.	κ	Aquilæ	— 0.27	+0.02	+0.12	+0.02	19 32 08.06	19 30 16.57	—1 51.49	1.
	λ	Ursæ Minoris	+12.98			+0.01	19 50 12.49	19 48 21.00	—1 51.49	0.002
	1	Draconis, (L. C.)	— 1.46			—0.01	21 21 07.08	9 19 15.68	—1 51.40	0.042
D.	ξ	Aquarii	— 0.19	+0.00	+0.12	—0.01	21 33 04.11	21 31 12.58	—1 51.53	1.
D.	ε	Pegasi	— 0.13	+0.00	+0.12	—0.01	21 40 00.42	21 38 09.06	—1 51.36	1.
D.	μ	Capricorni	— 0.20	+0.00	+0.12	—0.01	21 48 27.26	21 46 35.81	—1 51.45	1.
D.	20	Pegasi	— 0.11	+0.01	+0.12	—0.02	21 56 57.62	21 55 06.18	—1 51.44	1.
D.	α	Aquarii	— 0.15	+0.01	+0.12	—0.02	22 01 19.80	21 59 28.32	—1 51.48	1.
D.	θ	Pegasi	— 0.13	+0.02	+0.12	—0.02	22 05 51.59	22 04 00.04	—1 51.55	1.
D.	θ	Aquarii	— 0.16	+0.02	+0.12	—0.02	22 12 12.49	22 10 20.96	—1 51.53	1.
R.	γ	Aquarii	— 0.14	—0.02	—0.14	—0.02	22 17 10.04	22 15 18.52	—1 51.52	1.
R.	π	Aquarii	— 0.13	—0.02	—0.14	—0.02	22 20 51.57	22 19 00.04	—1 51.53	1.
R.	η	Aquarii	— 0.13	—0.02	—0.14	—0.03	22 30 54.01	22 29 02.44	—1 51.57	1.
R.	ζ	Pegasi	— 0.10	—0.03	—0.15	—0.03	22 37 11.44	22 35 19.86	—1 51.58	1.
R.	λ	Pegasi	— 0.06	—0.04	—0.16	—0.03	22 42 28.08	22 40 36.66	—1 51.42	1.
R.	η	Pegasi	— 0.06	—0.04	—0.16	—0.03	22 45 55.80	22 44 04.24	—1 51.56	1.
R.	λ	Aquarii	— 0.14	—0.02	—0.15	—0.03	22 48 03.72	22 46 12.13	—1 51.59	1.
		Carr. 3525	+ 1.01			—0.03	22 57 16.09	22 55 24.50	—1 51.59	0.027

From δ Ursæ Minoris, $c = +0^s.075$, tels. direct, $a = -0^s.405$
From λ Ursæ Minoris, $c = +0^s.151$, tels. direct, $a = -0^s.332$
From 1 Draconis, $c = +0^s.052$, tels. direct, $a = -0^s.250$
From Carr. 3525, $c = +0^s.091$, tels. direct, $a = -0^s.169$

Mean .... $c = \pm 0^s.092$, $\left\{ \begin{array}{l} \text{tels. direct.} \\ \text{tels. reversed.} \end{array} \right.$

$c + \Delta i + a b r = +0^s.115$, tels. direct.
$c + \Delta i + a b r = -0^s.145$, tels. reversed.
$\theta = -1^m\ 51^s.5$ at $20^h\ 48^m$, clock-time.

Normal equations.

$$+26^s.093\ \delta\theta - 1^s.340\ \rho = -0^s.280$$
$$-1^s.340 \qquad + 71^s.425 \quad = -1^s.026$$

$\delta\theta = -0^s.012$; $\rho = -0^s.0145$.

$\Delta t_0 = -1^m\ 51^s.512$ at $20^h\ 48^m$ clock-time

TABLE 4.—*Detroit, August 23, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	A (a+δa.)	B b	C (c+Δi+abr)	rβ	t'	α	Δt'	p
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
	δ Ursæ Minoris	+5.21	....	....	+0.04	18 14 10.96	18 12 17.50	−1 53.46	0.022
R.	1 Aquilæ	−0.34	+0.01	−0.17	+0.03	18 30 24.71	18 28 30.65	−1 54.06	1.
R.	α Lyræ	−0.04	+0.03	−0.22	+0.03	18 34 40.73	18 32 46.83	−1 53.90	1.
R.	110 Herculis	−0.18	+0.04	−0.18	+0.03	18 42 16.26	18 40 22.31	−1 53.95	1.
R.	β Lyræ	−0.08	+0.05	−0.20	+0.03	18 47 26.62	18 45 32.63	−1 53.99	1.
R.	θ' Serpentis	−0.27	+0.04	−0.17	+0.03	18 52 00.32	18 50 06.21	−1 54.11	1.
R.	ε Aquilæ	−0.21	+0.06	−0.17	+0.03	18 55 56.55	18 54 02.52	−1 54.03	1.
D.	ζ Aquilæ	−0.22	+0.08	+0.14	+0.03	19 01 39.54	18 59 45.44	−1 54.10	1.
D.	ι Lyræ	−0.06	+0.08	+0.17	+0.02	19 04 49.22	19 02 55.21	−1 54.01	1.
D.	ω Aquilæ	−0.23	+0.04	+0.14	+0.02	19 13 56.79	19 12 02.71	−1 54.08	1.
D.	δ Aquilæ	−0.28	+0.03	+0.14	+0.02	19 21 11.93	19 19 17.85	−1 54.08	1.
D.	β Cygni	−0.12	+0.06	+0.16	+0.02	19 27 40.10	19 25 46.02	−1 54.08	1.
D.	κ Aquilæ	−0.34	−0.02	+0.14	+0.02	19 32 10.56	19 30 16.54	−1 54.02	1.
	λ Ursæ Minoris	+17.25	....	....	+0.01	19 50 08.93	19 48 16.14	−1 52.79	0.002
D.	ξ Aquarii	−0.34	+0.06	+0.14	−0.01	21 33 06.63	21 31 12.60	−1 54.03	1.
D.	ε Pegasi	−0.24	+0.06	−15.98	−0.02	21 40 03.08	21 38 09.10	−1 53.98	0.89
D.	μ Capricorni	−0.38	+0.03	+0.14	−0.02	21 48 29.89	21 46 35.85	−1 54.04	1.
D.	20 Pegasi	−0.22	+0.04	+0.14	−0.02	21 57 00.18	21 55 06.22	−1 53.96	1.
D.	α Aquarii	−0.30	+0.03	+0.14	−0.02	22 01 22.42	21 59 28.37	−1 54.05	1.
D.	θ Pegasi	−0.26	+0.02	−8.49	−0.02	22 06 54.13	22 04 00.08	−1 54.05	0.97
D.	θ Aquarii	−0.34	+0.01	+0.14	−0.02	22 12 15.07	22 10 21.01	−1 54.06	1.
R.	γ Aquarii	−0.31	+0.03	−0.17	−0.02	22 17 12.6	22 15 18.58	−1 54.03	1.
R.	π Aquarii	−0.29	+0.04	−0.17	−0.02	22 20 54.10	22 19 00.10	−1 54.00	1.
R.	η Aquarii	−0.30	+0.07	−0.17	−0.03	22 30 56.58	22 29 02.50	−1 54.08	1.
R.	ζ Pegasi	−0.24	+0.08	−5.54	−0.03	22 37 14.02	22 35 19.92	−1 54.10	1.
R.	λ Pegasi	−0.16	+0.09	−0.18	−0.03	22 42 30.75	22 40 36.73	−1 54.02	1.
R.	ε Pegasi	−0.15	+0.09	−0.18	−0.03	22 45 58.35	22 44 04.31	−1 54.04	1.
R.	λ Aquarii	−0.34	+0.06	+8.44	−0.03	22 48 06.25	22 46 12.21	−1 54.04	1.
	Carr. 3525	+2.65	....	....	−0.03	22 57 19.23	22 55 24.73	−1 54.50	0.027
	Carr. 3621	+5.23	....	....	−0.04	23 29 54.89	23 27 59.85	−1 55.04	0.022
R.	ψ Pegasi	−0.19	+0.04	−0.18	−0.05	23 48 08.00	23 46 14.04	−1 53.96	1.
R.	ω Piscium	−0.26	+0.06	−0.17	−0.05	23 54 53.94	23 52 59.94	−1 54.00	1.

From δ Ursæ Minoris, $c = +0^s.103$, tels. direct.
From λ Ursæ Minoris, $c = +0^s.117$, tels. direct.
From Carr. 3525, $c = +0^s.125$, tels. direct.
From Carr. 3621, $c = +0^s.115$, tels. direct.

Mean.......... $c = +0^s.115$, { tels. direct. / tels. reversed.

$c + \Delta i + abr = +0^s.138$, tels. direct.
$c + \Delta i + abr = -0^s.168$, tels. reversed.
$a = 0^s.000$.
$= -1^m\ 54^s.0$ at $20^h\ 42^m$ clock-time.

Normal equations.

$$+27.933\,\delta\theta + 14.400\,\delta a + 7.460\,\rho = -7.330.$$
$$+14.400 \quad +19.608 \quad +7.042 = -9.216.$$
$$+7.460 \quad +7.042 \quad +91.289 = -4.750.$$

$\delta\theta = 0^s.031$; $\delta a = -0^s.441$; $\rho = -0^s.015$.

$\Delta t_0 = -1^m\ 54^s.031$ at $20^h\ 42^m$ clock-time.

TABLE 5.—*Detroit, August 25, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	A $(a+\delta a)$	Bb.	C $(c+\Delta i+abr)$	$r\rho$	t'	a.	Δt	p
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
	λ Ursæ Minoris	+11.54	....	....	+0.08	19 50 08.13	19 48 14.52	−1 53.61	0.002
D.	θ Aquilæ	− 0.20	+0.06	+0.09	+0.07	20 06 52.91	20 04 57.72	−1 55.19	1.
D.	24 Vulpeculæ	− 0.10	+0.12	+0.10	+0.07	20 13 26.82	20 11 31.70	−1 55.12	1.
D.	γ Cygni	− 0.02	+0.13	+0.11	+0.07	20 19 44.59	20 17 49.44	−1 55.15	1.
D.	π Capricorni	− 0.27	+0.05	+0.09	+0.06	20 22 12.37	20 20 17.13	−1 55.24	1.
D.	ε Delphini	− 0.16	+0.09	+0.09	+0.06	20 29 15.79	20 27 20.47	−1 55.32	1.
R.	α Delphini	− 0.14	+0.12	−0.12	+0.05	20 5 51.08	20 33 55.85	−1 55.23	1.
R.	δ Delphini	− 0.14	+0.10	−0.12	+0.05	20 39 38.51	20 37 43.32	−1 55.19	1.
R.	ε Aquarii	− 0.24	+0.07	−0.12	+0.05	20 42 56.58	20 41 01.34	−1 55.24	1.
R.	ν Cygni	− 0.01	+0.17	−0.15	+0.04	20 54 31.15	20 52 35.86	−1 55.29	1.
R.	61 Cygni	− 0.03	+0.18	−0.15	+0.04	21 03 18.65	21 01 23.56	−1 55.09	1.
R.	ξ Cygni	− 0.07	+0.16	−0.13	+0.03	21 09 37.66	21 07 42.54	−1 55.12	1.
	1 Draconis, (L. C.)	− 1.73	....	....	+0.03	21 21 10.86	9 19 16.16	−1 54.70	0.042
	Carr. 3525	+ 1.77	....	....	−0.04	22 57 19.95	22 55 24.78	−1 55.17	0.027
R.	τ Pegasi	− 0.11	+0.04	−0.13	−0.05	23 16 28.42	23 14 33.26	−1 55.16	1.
R.	υ Pegasi	− 0.11	+0.07	−0.12	−0.05	23 21 09.96	23 19 14.71	−1 55.25	1.
R.	θ Piscium	− 0.18	+0.07	−0.12	−0.05	23 23 39.30	23 21 44.01	−1 55.29	1.
R.	72 Pegasi	− 0.07	+0.10	−0.14	−0.06	23 29 46.56	23 27 51.24	−1 55.32	1.
R.	ι Andromedæ	− 0.00	+0.08	−0.16	−0.06	23 34 01.80	23 32 06.60	−1 55.20	1.
R.	ι Piscium	− 0.18	+0.04	−0.12	−0.06	23 35 32.99	23 33 37.77	−1 55.22	1.
D.	ψ Pegasi	− 0.13	+0.07	+0.09	−0.07	23 48 09.33	23 46 14.07	−1 55.26	1.
D.	ω Piscium	− 0.17	+0.03	+0.09	−0.07	23 54 55.13	23 52 59.98	−1 55.15	1.
D.	α Andromedæ	− 0.08	+0.08	+0.10	−0.08	00 03 57.07	00 02 01.98	−1 55.09	1.
D.	γ Pegasi	− 0.14	+0.07	+0.09	−0.08	00 08 49.52	00 06 54.32	−1 55.20	1.
D.	ι Ceti	− 0.24	+0.05	+0.09	−0.09	00 15 05.16	00 13 10.00	−1 55.16	1.
D.	12 Ceti	− 0.22	+0.07	+0.09	−0.09	00 25 41.16	00 23 45.97	−1 55.19	1.
	32 Camelop. (L. C.)	− 2.30	....	....	−0.11	00 50 05.49	12 48 10.94	−1 54.55	0.016

s.
From λ Ursæ Minoris, $c = +\ 0.066$, tels. direct.
From 1 Draconis, $c = +\ 0.053$, tels. direct.
From Carr. 3525, $c = +\ 0.075$, tels. direct.
From 32 Camelop., $c = +\ 0.057$, tels. direct.

Mean .... $c = +\ 0.063$, { tels. direct. / tels. reversed.
$a = \ 0.0$
$c + \Delta i + abr = +\ 0.086$, tels. direct.
$c + \Delta i + abr = -\ 0.116$, tels. reversed.
$\theta = 1^{m}\ 5?.2$ at 22^{h}, clock-time.

$$+\ 23.089\ \delta\theta + 10.290\ \delta a +\ 5.980\ \rho = -\ 3.300.$$
$$+\ 10.290\ \ \ \ \ \ +\ 12.521\ \ \ \ \ +\ 3.473\ \ \ \ = -\ 3.836.$$
$$+\ 5.980\ \ \ \ \ \ +\ 3.473\ \ \ \ \ +\ 62.207\ \ \ = -\ 3.418.$$

$\delta\theta = -\ 0^{s}.001 \quad \delta a = -\ 0^{s}.295 \quad \rho = -\ 0^{s}.039.$
$\Delta t_0 = -\ 1^{m}\ 55^{s}.201$ at 22^{h}, clock-time.

TABLE 6.—*Detroit, August 26, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	A $(a+\delta a)$	B b	C $(c+\Delta i+abr)$	$r\rho$	t'	α	$\Delta t'$	p
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
	λ Ursæ Minoris	+11.39	....	....	+0.03	19 50 06.24	19 48 13.61	−1 52.63	0.009
D.	θ Aquilæ	− 0.20	+0.03	+0.17	+0.03	20 06 53.24	20 04 57.72	−1 55.52	1.
D.	24 Vulpeculæ	− 0.10	+0.04	+0.19	+0.03	20 13 27.26	20 11 31.70	−1 55.56	1.
D.	γ Cygni	− 0.02	+0.04	+0.22	+0.02	20 19 44.87	20 17 49.43	−1 55.44	1.
D.	π Capricorni	− 0.27	0.00	+0.18	+0.02	20 22 12.76	20 20 17.12	−1 55.64	1.
D.	ε Delphini	− 0.15	0.00	+0.17	+0.02	20 29 16.08	20 27 20.46	−1 55.62	1.
R.	α Delphini	− 0.14	+0.01	−0.21	+0.02	20 35 51.38	20 33 55.85	−1 55.53	1.
R.	δ Delphini	− 0.14	+0.02	−0.21	+0.02	20 39 38.89	20 37 43.32	−1 55.57	1.
R.	ε Aquarii	− 0.23	+0.03	−0.20	+0.02	20 42 57.00	20 41 01.34	−1 55.66	1.
R.	ν Cygni	− 0.01	+0.07	−0.26	+0.02	20 54 31.28	20 52 35.86	−1 55.42	1.
R.	61 Cygni	− 0.03	+0.14	−0.26	+0.01	21 03 19.03	21 01 23.55	−1 55.48	1.
R.	ζ Cygni	− 0.07	+0.12	−0.23	+0.01	21 09 38.10	21 07 42.53	−1 55.57	1.
	1 Draconis, (L. C.)	− 1.70	....	....	−0.01	21 21 10.99	9 19 16.23	−1 54.76	0.042
	Carr. 3525	+ 1.75	....	....	−0.02	22 57 20.59	22 55 24.80	−1 55.79	0.027
R.	τ Pegasi	− 0.10	+0.03	−0.22	−0.02	23 16 28.95	23 14 33.28	−1 55.67	1.
R.	υ Pegasi	− 0.10	+0.05	−0.22	−0.02	23 21 10.28	23 19 14.72	−1 55.56	1.
R.	θ Piscium	− 0.17	+0.05	−0.20	−0.02	23 23 39.63	23 21 44.03	−1 55.60	1.
R.	72 Pegasi	− 0.07	+0.07	−0.23	−0.02	23 29 46.92	23 27 51.25	−1 55.67	1.
R.	ι Andromedæ	− 0.00	+0.08	−0.27	−0.02	23 34 02.16	23 32 06.62	−1 55.54	1.
R.	ι Piscium	− 0.18	+0.05	−0.20	−0.02	23 35 33.32	23 33 37.79	−1 55.53	1.
D.	ψ Pegasi	− 0.13	+0.09	+0.18	−0.03	23 48 09.72	23 46 14.09	−1 55.63	1.
D.	ω Piscium	− 0.17	+0.05	+0.17	−0.03	23 54 55.46	23 52 59.99	−1 55.47	1.
D.	α Andromedæ	− 0.08	+0.07	+0.19	−0.03	00 03 57.47	00 02 02.00	−1 55.47	1.
D.	γ Pegasi	− 0.14	+0.05	+0.18	−0.03	00 08 49.85	00 06 54.34	−1 55.51	1.
D.	ι Ceti	− 0.23	+0.03	+0.17	−0.03	00 15 05.62	00 13 10.02	−1 55.60	1.
D.	12 Ceti	− 0.21	+0.03	+0.17	−0.04	00 25 41.47	00 23 45.99	−1 55.48	1.
	32 Camelopardalis, (L. C.)	− 2.27	....	....	−0.04	00 48 04.98	12 48 10.82	−1 54.16	0.018

From λ Urs. Minoris, $c = +0.128$ s., tels. direct.
From 1 Draconis, $c = +0.117$, tels. direct.
From Carr. 3525, $c = +0.169$, tels. direct.
From 32 Camelop., $c = +0.180$, tels. direct.

Mean.......... $c = \pm 0.148$, $\left\{\begin{array}{l}\text{tels. direct.}\\ \text{tels. reversed.}\end{array}\right.$

$a = 0.000$

$c + \Delta i + abr = +0.171$, tels. direct.

$c + \Delta i + abr = -0.201$, tels. reversed.

$\theta = -1^m\ 55^s.6$ at $21^h\ 57^m$, clock-time.

Normal equations.

$$+23.069\,\delta\theta + 10.280\,\delta a + 7.160\,\rho = -1.950$$
$$+10.280 \quad + 12.521 \quad + 4.011 \quad = -3.192$$
$$+7.160 \quad + 4.011 \quad + 62.905 \quad = -1.784$$

$\delta\theta = +0^s.050 \quad \delta a = -0^s.291 \quad \rho = -0^s.015$

$\Delta t_0 = -1^m\ 55^s.550$ at $21^h\ 57^m$, clock-time.

TABLE 7.—*Detroit, October 23, 1876.—Observer, H. M. Adams.*

Tels.	Star.	A $(a+\delta a.)$	Bb.	C $(c+\Delta i+abr.)$	rp.	t'.	α.	Δt'.	p.
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
	1 Draconis L. C	+0.95	......	......	−0.03	21 21 33.29	9 19 23.58	−2 09.71	0.042
R.	ξ Aquarii	+0.13	+0.07	+ 2.15	−0.03	21 33 22.13	21 31 12.21	−2 09.92	1.
R.	ε Pegasi	+0.09	+0.10	− 0.12	−0.03	21 40 18.43	21 38 08.69	−2 09.74	1.
R.	μ Capricorni	+0.14	+0.06	− 0.12	−0.03	21 48 45.42	21 46 35.53	−2 09.89	1.
R.	20 Pegasi	+0.08	+0.11	− 0.12	−0.02	21 57 15.73	21 55 05.91	−2 09.82	1.
R.	α Aquarii	+0.11	+0.09	− 0.12	−0.02	22 01 37.92	21 59 28.10	−2 09.82	1.
R.	θ Pegasi	+0.10	+0.11	− 0.12	−0.02	22 06 09.70	22 03 59.82	−2 09.88	1.
R.	υ Aquarii	+0.13	+0.09	− 0.12	−0.02	22 12 30.71	22 10 20.81	−2 09.90	1.
D.	γ Aquarii	+0.11	+0.10	+ 0.09	−0.02	22 17 28.07	22 15 18.40	−2 09.67	1.
D.	π Aquarii	+0.11	+0.11	+ 0.09	−0.02	22 21 09.66	22 18 59.93	−2 09.73	1.
D.	η Aquarii	+0.11	+0.11	+ 0.09	−0.01	22 31 12.19	22 29 02.40	−2 09.79	1.
D.	ζ Pegasi	+0.09	+0.13	+ 0.09	−0.01	22 37 29.68	22 35 19.83	−2 09.85	1.
D.	λ Pegasi	+0.06	+0.16	+ 0.10	−0.01	22 42 46.45	22 40 36.60	−2 09.85	1.
D.	μ Pegasi	+0.06	+0.15	+ 0.10	−0.01	22 46 13.97	22 44 04.21	−2 09.76	1.
D.	λ Aquarii	+0.13	+0.09	+ 0.09	−0.01	22 48 22.07	22 46 12.19	−2 09.88	1.
	Carr. 3525	−0.97	......	......	−0.01	22 57 30.96	22 55 21.12	−2 09.84	0.027
R.	ψ Pegasi	+0.07	+0.08	− 0.13	+0.01	23 48 24.18	23 46 14.37	−2 09.81	1.
R.	ω Piscium	+0.10	+0.04	− 0.12	+0.01	23 55 10.03	23 53 00.31	−2 09.72	1.
R.	α Andromedæ	+0.05	+0.10	− 0.14	+0.01	00 04 12.10	00 02 02.38	−2 09.72	1.
R.	γ Pegasi	+0.08	+0.07	− 0.12	+0.02	00 09 04.53	00 06 54.74	−2 09.79	1.
R.	ι Ceti	+0.13	+0.03	− 0.12	+0.02	00 15 20.23	00 13 10.45	−2 09.78	1.
R.	Carr. 76	−0.72	......	......	+0.02	00 32 46.73	00 30 36.78	−2 09.94	0.062
D.	δ Piscium	+0.09	+0.08	+ 0.09	+0.03	00 44 28.50	00 42 18.74	−2 09.85	1.
D.	μ Andromedæ	+0.02	+0.12	+ 0.12	+0.03	00 52 06.28	00 49 56.41	−2 09.87	1.
D.	ε Piscium	+0.09	+0.05	+ 0.09	+0.03	00 58 44.15	00 56 34.36	−2 09.79	1.
D.	τ Piscium	+0.04	+0.06	−19.71	+0.03	01 07 03.74	01 04 54.07	−2 09.67	0.950
D.	υ Piscium	+0.05	+0.06	+ 0.10	+0.04	01 14 53.06	01 12 43.16	−2 09.90	1.
D.	θ' Ceti	+0.13	+0.05	+ 1.96	+0.04	01 20 03.25	01 17 53.46	−2 09.79	1.
D.	η Piscium	+0.08	+0.06	+ 0.09	+0.04	01 27 04.72	01 24 54.82	−2 09.90	1.
R.	ν Piscium	+0.10	+0.04	− 0.12	+0.04	01 37 12.58	01 35 02.67	−2 09.91	1.
R.	ο Piscium	+0.09	+0.06	− 0.12	+0.04	01 41 04.61	01 38 54.81	−2 09.80	1.
	Carr. 299	−0.86	......	......	+0.05	02 00 22.55	01 58 12.78	−2 09.77	0.037

From 1 Draconis $c = +0^s.076$, tels. direct.
From Carr. 3,525 $c = +0^s.046$, tels. direct.
From Carr. 76 $c = +0^s.094$, tels. direct.
From Carr. 299 $c = +0^s.054$, tels. direct.

Mean..... $c = \pm 0^s.068$, { tels. direct. / tels. reversed.

$a = 0^s.000$.

$c + \Delta i + abr = +0^s.091$, tels. direct.
$c + \Delta i + abr = -0^s.121$, tels. reversed.
$\theta = -2^m\ 09^s.82$ at $23^h\ 18^m$ clock time.

Normal equations.

$$+28.118\,\delta\theta + 15.270\,\delta a + 6.250\,\rho = +2.780$$
$$+15.270 \qquad + 14.439 \qquad - 0.607 = +2.436$$
$$+6.250 \qquad - 0.607 \qquad + 55.339 = +0.936$$

$\delta\theta = +0^s.007 \qquad \delta a = +0^s.162 \qquad \rho = +0^s.018$

$\Delta t_0 = -2^m\ 09^s.813$ at $23^h\ 18^m$ clock-time.

TABLE 8.—*Detroit, July 17, 1876.—Observer, H. M. Adams.*

Tels.	Star.	A a	B b	C (c+Δi+abr).	t'₀	α	Δt	r ρ	Δt'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
R.	ζ Herculis	+0.27	+0.05	−0.20	16 38 16.51	16 36 39.40	−1 37.11	+0.02	−1 37.13
	ε Ursæ Minoris					58 49.49			
D.	π Herculis	+0.15	+0.15	+0.17	17 12 23.82	17 10 46.48	37.34	+0.01	1 37.35
D.	α Ophiuchi	+0.65	+0.11	−0.14	30 50.05	29 13.57	37.48	+0.01	1 37.49
D.	β Ophiuchi	+0.79	+0.10	+0.13	39 01.30	37 23.78	37.52	+0.01	1 37.53
D.	γ Ophiuchi	+0.82	+0.09	+0.13	43 20.99	41 43.44	37.55	+0.01	1 37.56
D.	θ Herculis	+0.14	+0.15	+3.81	53 40.24	52 02.81	37.43	+0.01	1 37.44
R.	72 Ophiuchi	+0.70	+0.07	−0.17	18 03 08.62	18 01 31.22	37.40	+0.01	1 37.41
R.	γ Aquilæ	+0.69	+0.09	−0.17	19 42 02.32	19 40 24.90	37.42	−0.01	1 37.41
R.	α Aquilæ	+0.72	+0.09	−0.17	46 24.50	44 47.05	37.45	−0.01	1 37.44
R.	β Aquilæ	+0.76	+0.09	−0.17	50 53.93	49 16.40	37.53	−0.01	1 37.52
R.	τ Aquilæ	+0.75	+0.09	−0.17	59 45.52	58 08.02	37.50	−0.01	1 37.49
R.	θ Aquilæ	+0.88	+0.08	−0.17	20 06 35.06	20 04 57.57	37.49	−0.01	1 37.48
D.	γ Cygni	+0.07	+0.17	+0.17	19 26.66	17 49.44	37.22	−0.02	1 37.21
D.	π Capricorni	+1.18	+0.07	+0.14	21 54.29	20 16.89	37.40	−0.02	1 37.39
	Groom. 3,241					30 34.70			
	12 year cat., 1879					53 12.61			
	Mean =								−1 37.42

s.
From ε Ursæ Minoris, $c=+0.109$, tels. direct.
From Groom., 3,241, $c=+0.209$, tels. direct.
From 12 year cat., 1879, $c=+0.162$, tels. direct.

Mean......$c=\pm 0.160$ { tels. direct. / tels. reversed.

$c+\Delta i+abr=+0.134$, tels. direct.
$c+\Delta i+abr=-0.166$, tels. reversed.

s.
$a=+1.268$
$a=+1.273$
$a=+1.310$

Mean......$a=+1.284$

$\Delta t_0=-1^m 37^s.42$ at $18^h\ 42^m$ clock-time.
$\rho=-\ 0^s.01$

TABLE 9.—*Detroit, July 22, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	A a	B b	C (c+Δi+a b r)	t'_0	α	Δ t	r ρ	Δ t'
		s.	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*s.*	*m. s.*
R.	ε Herculis	+0.01	−0.09	−0.24	16 57 15.60	16 55 35.39	−1 40.21	−0.12	−1 40.09
R.	60 Herculis	+0.04	−0.06	−0.21	17 01 20.85	16 59 40.47	1 40.38	−0.11	1 40.27
R.	Groombridge, 2415	0.00	−0.09	−0.28	17 05 27.02	17 03 46.48	1 40.54	−0.10	1 40.44
R.	a¹ Herculis	+0.03	−0.06	−0.21	17 10 42.70	17 09 02.39	1 40.31	−0.09	1 40.22
R.	π Herculis	+0.01	−0.04	+5.94	17 12 26.76	17 10 46.43	1 40.33	−0.09	1 40.24
R.	α Ophiuchi	+0.03	−0.04	−0.21	17 30 53.80	17 29 13.55	1 40.25	−0.06	1 40.19
	51 Cephei, L. C					6 41 39.54			
R.	ε Aquilæ	+0.03	−0.10	−0.22	18 55 42.90	18 54 02.66	1 40.24	+0.08	1 40.32
D.	ζ Aquilæ	+0.03	−0.08	+0.18	19 01 25.72	59 45.57	1 40.15	+0.09	1 40.24
D.	ι Lyræ	+0.01	−0.11	−3.33	19 04 35.54	19 02 55.46	1 40.08	+0.10	1 40.18
D.	ω Aquilæ	+0.03	−0.08	+0.18	19 13 42.92	19 12 02.78	1 40.14	+0.11	1 40.25
D.	δ Aquilæ	+0.04	−0.04	+0.18	19 20 58.09	19 19 17.91	1 40.18	+0.12	1 40.30
D.	β Cygni	+0.02	−0.07	+0.20	19 27 26.15	19 25 46.14	1 40.01	+0.14	1 40.15
D.	κ Aquilæ	+0.05	−0.05	+0.18	19 31 56.64	19 30 16.54	1 40.10	+0.14	1 40.24
	λ Ursæ Minoris					19 48 35.94			
	Mean								−1 40.24

From 51 Cephei, $c = +0^s.213$, tels. direct.
From λ Urs. Minoris, $c = +0.196$, tels. direct.

Mean.... $c = \pm 0.204$, { tels. direct. / tels. reversed.

$c + \Delta i + a b r = +0.177$, tels. direct.
$c + \Delta i + a b r = -0.209$, tels. reversed.

$a = +0^s.101$
$a = +0.029$

Mean.... $a = +0.065$

$\Delta t_0 = -1^m\ 40^s.24$ at $18^h\ 06^m$ clock-time.
$\rho = +\ 0^s.10$

TABLE 10.—*Detroit, July 28, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	A a	B b	C $(c+\Delta i+a\,b\,r)$	t'_0	a	Δt	$r\,\rho$	$\Delta t'$
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
R.	γ Hericulis	−0.03	−0.13	− 0.21	16 18 11.57	16 16 29.50	−1 42.07	+0.13	−1 42.20
R.	ζ Ophuchi	−0.05	−0.10	− 4.00	16 32 04.83	16 30 22.75	1 42.08	+0.12	1 42.20
R.	ζ Herculis	−0.01	−0.19	− 0.23	16 38 21.18	16 36 39.27	1 41.91	+0.11	1 42.02
R.	η Herculis	0.00	−0.22	− 0.25	16 40 23.17	16 38 41.20	1 41.97	+0.11	1 42.08
	Ursæ Minoris					16 58 47.97			
D.	c^1 Herculis	−0.03	−0.10	+ 0.17	17 10 44.31	17 09 02.35	1 41.96	+0.07	1 42.03
D.	π Herculis	−0.01	−0.14	+ 0.20	17 12 28.20	17 10 46.36	1 41.84	+0.07	1 41.91
D.	α Ophiuchi	−0.03	−0.12	+ 0.17	17 30 55.55	17 29 13.53	1 42.02	+0.04	1 42.06
D.	β Ophiuchi	−0.04	−0.09	+ 0.16	17 39 05.72	17 37 23.73	1 41.99	+0.03	1 42.02
D.	1 Aquilæ	−0.05	−0.09	+ 0.16	18 30 13.06	18 28 30.79	1 42.27	−0.03	1 42.24
D.	α Lyræ	−0.01	−0.18	+ 0.21	18 34 29.13	18 32 47.17	1 41.96	−0.03	1 41.93
D.	ϵ Aquilæ	−0.03	−0.11	+16.51	18 55 44.84	18 54 02.65	1 42.19	−0.06	1 42.13
D.	ζ Aquilæ	−0.03	−0.11	+ 0.17	19 01 27.79	18 59 45.58	1 42.21	−0.07	1 42.14
R.	δ Aquilæ	−0.04	−0.09	− 0.19	19 21 00.19	19 19 17.93	1 42.26	−0.09	1 42.17
R.	β Cygni	−0.02	−0.16	− 0.22	19 27 28.32	19 25 46.14	1 42.18	−0.10	1 42.08
	λ Ursæ Minoris					19 48 34.04			
D.	24 Vulpeculæ	−0.02	−0.18	+ 0.18	20 13 13.75	20 11 31.70	1 42.05	−0.16	1 41.89
R.	γ Cygni	0.00	−0.22	− 0.25	20 19 31.68	20 17 49.51	1 42.17	−0.17	1 42.00
R.	ϵ Delphini	−0.03	−0.15	− 0.20	20 29 02.65	20 27 20.41	1 42.24	−0.18	1 42.06
	α Delphini	−0.03	−0.18	− 0.20	20 35 37.97	20 33 55.76	1 42.21	−0.18	1 42.03

From ϵ Urs. Minoris, $c = +0^s.191$, tels. direct.
From λ Urs. Minoris, $c = +0.187$, tels. direct.

Mean........ $c = \pm 0.189$ { tels. direct. / tels. reversed.
$c + \Delta i + a\,b\,r = +0.162$, tels. direct.
$c + \Delta i + a\,b\,r = -0.194$, tels. reversed.

$a = -0.113$.
$a = -0.011$.

Mean...... $a = -0.062$.

$\Delta t_0 = -1^m\ 42^s.07$ at $18^h\ 06^m$ clock-time.
$\rho = -\ 0^s.074$.

TABLE 11.—*Detroit, July 31, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	$A a$	$B b$	$C(c+\Delta i+a b r)$	t'_0	α	Δt	$\tau \rho$	$\Delta t'$
		s.	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*s.*	*m. s.*
R.	α Ophiuchi	−0.03	+0.04	−0.20	17 30 56.78	17 29 13.50	−1 43.28	+0.05	−1 43.33
R.	β Ophiuchi	−0.03	+0.05	−0.20	17 39 07.00	17 37 23.73	1 43.27	+0.04	1 43.31
R.	γ Ophiuchi	−0.03	+0.05	−0.20	17 43 26.74	17 41 43.41	1 43.33	+0.04	1 43.37
D.	θ Herculis	−0.01	+0.06	+0.21	17 53 45.73	17 52 02.70	1 43.03	+0.03	1 43.06
D.	67 Ophiuchi	−0.03	+0.05	+0.16	17 56 12.24	17 54 29.09	1 43.15	+0.03	1 43.18
D.	72 Ophiuchi	−0.03	+0.06	+0.17	18 03 14.34	18 01 31.19	1 43.15	+0.03	1 43.18
	δ Ursæ Minoris					18 12 25.26			
R.	ω Aquilæ	−0.03	+0.06	−0.20	19 13 46.23	19 12 02.79	1 43.44	−0.01	1 43.43
R.	δ Aquilæ	−0.03	+0.06	−0.20	19 21 01.27	19 19 17.94	1 43.33	−0.01	1 43.32
R.	β Cygni	−0.01	+0.09	−0.22	19 27 29.32	19 25 46.16	1 43.16	−0.01	1 43.15
R.	κ Aquilæ	−0.04	+0.06	−0.20	19 32 00.04	19 30 16.58	1 43.46	−0.02	1 43.44
	λ Ursæ Minoris					19 48 32.62			
D.	α^2 Capricorni	−0.04	+0.07	+0.17	20 12 57.23	20 11 13.98	1 43.25	−0.04	1 43.21
D.	γ Cygni	0.00	+0.18	+0.21	20 19 32.60	20 17 49.54	1 43.06	−0.04	1 43.02
D.	π Capricorni	−0.05	+0.07	+0.17	20 22 00.24	20 20 17.06	1 43.18	−0.04	1 48.14
D.	ϵ Delphini	−0.03	+0.12	+0.17	20 29 03.68	20 27 20.43	1 43.25	−0.05	1 43.20
	Mean								−1 43.24

From δ Ursæ Minoris, $c = +\,0^{s}.185$, tels. direct.
From λ Ursæ Minoris, $c = +\,0.197$, tels. direct.

Mean $c = \pm\,0.191$, $\left\{\begin{array}{l}\text{tels. direct.}\\ \text{tels. reversed.}\end{array}\right.$

$c + \Delta i + a b r = +\,0.164$, tels. direct.
$c + \Delta i + a b r = -\,0.196$, tels. reversed.

$a = -\,0^{s}.105$
$a = +\,0.001$

Mean $a = -\,0.052$

$\Delta t_0 = -\,1^{m}\,43^{s}.24$ at 19^{h} clock-time.
$\rho = -\ \ 0.032$

TABLE 12.—*Detroit, September 1, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	Aa	Bb	$C(c+\Delta i+abr)$	t'_0	α	Δt	$r\rho$
		s.	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*s.*
R.	ε Aquilæ	−0.17	+0.17	−0.12	18 56 00.29	18 54 02.41	−1 57.88	+0.00
R.	ξ Aquilæ	−0.17	+0.18	−0.12	19 01 43.23	18 59 45.34	1 57.89	
R.	ι Lyræ	−0.05	+0.25	−0.14	19 04 52.78	19 02 55.06	1 57.72	
D.	ω Aquilæ	−0.18	+0.16	+0.09	19 14 00.65	19 12 02.62	1 58.03	
D.	δ Aquilæ	−0.22	+0.14	+0.08	19 21 15.91	19 19 17.77	1 58.14	
D.	β Cygni	−0.10	+0.14	+0.10	19 27 43.88	19 25 45.91	1 57.97	+0.00
	λ Ursæ Minoris					19 48 07.31		
	Mean						−1 57.94	

From λ Urs. Minoris, $c = \pm 0^s.111$ $\begin{cases}\text{tels. direct.}\\ \text{tels. reversed.}\end{cases}$

$c+\Delta i+abr = +0.084$, tels. direct.

$c+\Delta i+abr = -0.116$, tels. reversed.

$a = -0^s.348$

$\Delta t_0 = -1^m\ 57^s.94$ at $19^h\ 11^m$ clock-time,

$\rho = -0.017$, (from Aug. 26.)

TABLE 13.—*Detroit, September 12, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	Aa	Bb	$C(c+\Delta i+abr)$	t'_o	a	Δt	$r\rho$	$\Delta t'$
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
	λ Ursæ Minoris					19 47 55.51			
D.	θ Aquilæ	+0.27	0.00	+0.07	20 06 59.05	20 04 57.57	−2 01.48	+0.02	−2 01.50
D.	24 Vulpeculæ	−0.13	0.00	+0.07	20 13 32.98	20 11 31.51	2 01.47	0.02	2 01.49
D.	γ Cygni	−0.02	+0.00	+0.09	20 19 50.62	20 17 49.19	2 01.43	0.01	2 01.44
D.	π Capricorni	−0.36	+0.01	+0.07	20 22 18.56	20 20 17.00	2 01.56	0.01	2 01.57
D.	ε Delphini	−0.21	+0.02	+0.07	20 29 21.92	20 27 20.34	2 01.58	0.01	2 01.59
R.	κ Delphini	−0.18	+0.01	−0.10	20 35 57.37	20 33 55.73	2 01.64	0.01	2 01.65
R.	δ Delphini	−0.19	0.00	−0.10	20 39 44.78	20 37 43.19	2 01.59	0.01	2 01.60
R.	ε Aquarii	−0.31	0.00	−0.10	20 43 02.88	20 41 01.26	2 01.62	0.01	2 01.63
R.	ν Cygni	−0.02	+0.01	−0.13	20 54 37.16	20 52 35.68	2 01.48	0.01	2 01.49
R.	61¹ Cygni	−0.03	+0.02	−0.12	21 03 24.93	21 01 23.42	2 01.51	0.01	2 01.52
R.	ζ Cygni	−0.10	+0.02	−0.11	21 09 43.91	21 07 42.43	2 01.48	+0.01	2 01.49
	1 Draconis, (L. C.)					9 19 17.76			
	Carr., 3525					22 55 24.70			
R.	τ Pegasi	−0.14	+0.06	−0.11	23 16 35.04	23 14 33.43	2 01.61	−0.02	2 01.59
R.	υ Pegasi	−0.14	+0.07	−0.11	23 21 16.49	23 19 14.89	2 01.60	0.02	2 01.58
R.	θ Piscium	−0.23	+0.06	−0.10	23 23 45.94	23 21 44.19	2 01.75	0.02	2 01.73
R.	72 Pegasi	−0.09	+0.09	−0.11	23 29 53.10	23 27 51.42	2 01.68	0.02	2 01.66
R.	ι Andromedæ	0.00	+0.12	−0.13	23 34 08.40	23 32 06.82	2 01.58	0.02	2 01.56
R.	ι Piscium	−0.24	+0.07	−0.10	23 35 39.58	23 33 37.97	2 01.61	0.02	2 01.59
D.	χ Pegasi	−0.17	+0.07	+0.07	23 48 15.89	23 46 14.29	2 01.60	0.02	2 01.58
D.	ω Piscium	−0.23	+0.11	+0.07	23 55 01.76	23 53 00.21	2 01.55	0.02	2 01.53
D.	α Andromedæ	−0.10	+0.12	+0.07	00 04 03.67	00 02 02.25	2 01.42	0.03	2 01.39
D.	γ Pegasi	−0.19	+0.09	+0.07	00 08 56.03	00 06 54.58	2 01.45	0.03	2 01.42
D.	ι Ceti	−0.31	+0.06	+0.07	00 15 11.79	00 13 10.27	2 01.52	0.03	2 01.49
D.	12 Ceti	−0.28	+0.08	+0.07	00 25 47.79	00 23 46.25	2 01.54	−0.03	2 01.51
	32 Camelopardalis, (L. C.)					12 48 09.16			
	Mean								−2 01.548

From λ Ursæ Minoris, $c = +0.090$ s., tels. direct.
From 1 Draconis, $c = +0.093$, tels. direct.
From Carr., 3525, $c = +0.123$, tels. direct.
From 32 Camelopardalis, $c = +0.068$, tels. direct.

Mean .... $c = \pm 0.093$, { tels. direct. / tels. reversed.

$c + \Delta i + abr = +0.067$, tels. direct.
$c + \Delta i + abr = -0.097$, tels. reversed.

$a = -0.450$ s.
$a = -0.336$
$a = -0.432$
$a = -0.334$

Mean ... $a = -0.388$

$\Delta t_0 = -2^m\ 01^s.548$ at $21^h\ 41^m$ clock-time.
$\rho = -\ 0.011$

TABLE 14.—*Detroit, September 16, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	A a	B b	C (c+Δi+abr)	t'_0	α	Δt	r ρ	Δt'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
	γ Ursæ Minoris					19 47 50.51			
D.	θ Aquilæ	—0.38	+0.10	+0.09	20 07 00.14	20 04 57.53	—2 02.61	+0.03	—2 02.64
D.	24 Vulpeculæ	—0.19	+0.14	+0.10	20 13 34.08	20 11 31.45	2 02.63	+0.03	2 02.66
D.	γ Cygni	—0.03	+0.15	+0.12	20 19 51.65	20 17 49.11	2 02.54	+0.03	2 02.57
D.	π Capricorni	—0.51	+0.06	+0.10	20 22 19.68	20 20 16.96	2 02.72	+0.03	2 02.75
D.	ε Delphini	—0.29	+0.09	+0.10	20 29 23.03	20 27 20.30	2 02.73	+0.03	2 02.76
R.	α Delphini	—0.26	+0.08	—0.13	20 35 58.30	20 33 55.69	2 02.61	+0.02	2 02.63
R.	δ Delphini	—0.26	+0.08	—0.13	20 39 45.93	20 37 43.15	2 02.78	+0.02	2 02.80
R.	ε Aquarii	—0.44	+0.05	—0.13	20 43 04.01	20 41 01.23	2 02.78	+0.02	2 02.80
R.	ν Cygni	—0.02	+0.11	—0.17	20 54 38.41	20 52 35.62	2 02.79	+0.02	2 02.81
R.	61[1]Cygni	—0.05	+0.13	—0.16	21 03 26.11	21 01 23.37	2 02.74	+0.01	2 02.75
R.	ζ Cygni	—0.14	+0.11	—0.15	21 09 45.17	21 07 42.39	2 02.78	+0.01	2 02.79
	1 Draconis, (L. C.)					9 19 18.21			
	Carr. 3525					22 55 24.56			
R.	τ Pegasi	—0.20	+0.14	—0.14	23 16 36.25	23 14 33.45	2 02.80	—0.03	2 02.77
R.	υ Pegasi	—0.20	+0.14	—0.14	23 21 17.73	23 19 14.92	2 02.81	—0.03	2 02.78
R.	θ Piscium	—0.33	+0.11	—0.13	23 23 47.01	23 21 44.21	2 02.80	—0.04	2 02.76
R.	72 Pegasi	—0.13	+0.15	—0.15	23 29 54.40	23 27 51.45	2 02.95	—0.04	2 02.91
R.	ι Andromedæ	+0.01	+0.17	—0.17	23 34 09.69	23 32 06.85	2 02.84	—0.04	2 02.80
R.	ι Piscium	—0.34	+0.10	—0.13	23 35 40.74	23 33 38.00	2 02.74	—0.04	2 02.70
D.	ψ Pegasi	—0.24	+0.12	+0.10	23 48 17.01	23 46 14.32	2 02.69	—0.04	2 02.65
D.	ω Piscium	—0.33	+0.10	—4.03	23 55 02.96	23 53 00.25	2 02.71	—0.05	2 02.66
D.	α Andromedæ	—0.15	+0.14	+0.11	00 04 04.92	00 02 02.29	2 02.63	—0.05	2 02.58
D.	γ Pegasi	—0.27	+0.12	+0.10	00 08 57.29	00 06 54.62	2 02.67	—0.05	2 02.62
	Means								—2 02.723

From λ Ursæ Minoris, $c = +0^s.092$, tels. direct.
From 1 Draconis, $c = +0.150$, tels. direct.
From Carr. 3525, $c = +0.124$, tels. direct.

Mean ...... $c = \pm 0.122$, { tels. direct. / tels. reversed.

$c + \Delta i + a\,b\,r = +0.095$, tels. direct.
$c + \Delta i + a\,b\,r = -0.127$, tels. reversed.

$a = -0^s.581$
$a = -0.494$
$a = -0.582$

Mean.... $a = -0.552$

$\Delta t_0 = -2^m\,02^s.723$ at $21^h\,43^m$ clock-time.
$\rho = -\ 0^s.021$

TABLE 15.—*Detroit, October 11, 1876—Observer, H. M. Adams.*

Tels.	Stars.	Aα	Bb	C (c+Δι+abr)	t_0'	α	Δt	rρ	Δt'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
	1 Draconis, (L. C)	......	......	......	......	9 19 21.62	......	......	......
R.	ξ Aquarii	+0.11	+0.02	−0.13	21 33 21.48	21 31 12.36	−2 09.12	−0.06	−2 09.06
R.	ε Pegasi	+0.08	+0.03	−0.13	21 40 17.75	21 38 08.84	2 08.91	−0.06	2 08.85
R.	μ Capricorni	+0.12	+0.02	−0.14	21 48 44.79	21 46 35.67	2 09.12	−0.05	2 09.07
R.	20 Pegasi	+0.07	+0.03	−0.14	21 57 15.05	21 55 06.05	2 09.00	−0.05	2 08.95
R.	α Aquarii	+0.10	+0.03	−0.13	22 01 37.31	21 59 28.23	2 09.08	−0.05	2 09.03
R.	θ Pegasi	+0.08	+0.03	−0.13	22 06 09.02	22 03 59.95	2 09.07	−0.05	2 09.02
R.	θ Aquarii	+0.11	+0.02	−0.13	22 12 30.13	22 10 20.93	2 09.20	−0.04	2 09.16
D.	γ Aquarii	+0.10	+0.05	+0.10	22 17 27.54	22 15 18.53	2 09.01	−0.04	2 08.97
D.	π Aquarii	+0.09	+0.04	+0.10	22 21 08.96	22 19 00.05	2 08.91	−0.04	2 08.87
D.	η Aquarii	+0.10	+0.03	+0.10	22 31 11.54	22 29 02.50	2 09.04	−0.03	2 09.01
D.	ζ Pegasi	+0.08	+0.03	+0.10	22 37 28.85	22 35 19.94	2 08.91	−0.03	2 08.88
D.	λ Pegasi	+0.05	+0.04	−0.91	22 42 45.61	22 40 36.72	2 08.89	−0.03	2 08.86
D.	μ Pegasi	+0.05	+0.05	+0.11	22 46 13.24	22 44 04.33	2 08.91	−0.03	2 08.88
D.	λ Aquarii	+0.11	+0.04	+0.10	22 48 21.31	22 46 12.29	2 09.02	−0.03	2 08.99
	Carr. 3525	......	......	......	......	22 55 22.62	......	......	......
	Carr. 76	......	......	......	......	00 30 37.11	......	......	......
D.	δ Piscium	+0.08	+0.08	+0.10	00 44 27.72	00 42 18.72	2 09.00	+0.03	2 09.03
D.	μ Andromedæ	+0.01	+0.14	+0.13	00 52 05.27	00 49 56.38	2 08.89	+0.03	2 08.92
D.	ε Piscium	+0.08	+0.10	+0.10	00 58 43.27	00 56 34.30	2 08.97	+0.03	2 09.00
D.	β Andromedæ	+0.02	+0.16	+0.13	01 05 00.39	01 02 51.53	2 08.86	+0.03	2 08.89
D.	τ Piscium	+0.04	+0.16	+0.12	01 07 02.89	01 04 54.00	2 08.89	+0.04	2 08.93
R.	υ Piscium	+0.04	+0.16	−0.15	01 14 51.93	01 12 43.09	2 08.84	+0.04	2 08.88
R.	θ Ceti	+0.11	+0.09	−0.13	01 20 02.22	01 17 53.39	2 08.83	+0.04	2 08.87
R.	η Piscium	+0.07	+0.18	−0.14	01 27 03.64	01 24 54.73	2 08.91	+0.04	2 08.95
R.	ν Piscium	+0.09	+0.14	−0.13	01 37 11.72	01 35 02.57	2 09.15	+0.05	2 09.20
R.	ο Piscium	+0.08	+0.15	−0.13	01 41 03.71	01 38 54.70	2 09.01	+0.05	2 09.06
	Carr. 299	......	......	......	......	01 58 12.19	......	......	......
	Mean								−2 08.972

From 1 Draconis, $c = +0.131$ s., tels. direct.
From Carr. 3525, $c = +0.119$, tels. direct.
From Carr. 76, $c = +0.125$, tels. direct.
From Carr. 299, $c = +0.142$, tels. direct.

Mean ...... $c = \pm 0.129$, { tels. direct. / tels. reversed.

$c + \Delta\iota + abr = +0.103$, tels. direct.
$c + \Delta\iota + abr = -0.133$, tels. reversed.

$a = +0.155$ s.
$a = +0.109$
$a = +0.156$
$a = +0.144$

Mean ... $a = +0.141$

$\Delta t_0 = -2^m\ 08^s.972$ at $20^h\ 48^m$ clock-time.
$\rho = +\ 0^s.027$

TABLE 16.—*Detroit, October 12, 1876.—Observer, H. M. Adams.*

Tels.	Stars.	A a	B b	C (c + Δι + abr)	t'ₐ	α	Δ t	r ρ	Δ t'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
	1 Draconis, (L. C.)					9 19 21.77			
R.	ξ Aquarii	+0.04	+0.07	− 0.13	21 33 21.37	21 31 12.35	−2 09.02	−0.06	−2 08.96
R.	ε Pegasi	+0.03	+0.07	− 0.13	21 40 17.74	21 38 08.83	2 08.91	−0.06	2 08.85
R.	μ Capricorni	+0.05	+0.04	+13.62	21 48 44.65	21 46 35.66	2 08.99	−0.06	2 08.93
R.	20 Pegasi	+0.03	+0.06	− 0.13	21 57 14.84	21 55 06.04	2 08.80	−0.05	2 08.75
R.	α Aquarii	+0.04	+0.06	− 0.79	22 01 37.13	21 59 28.22	2 08.91	−0.05	2 08.86
R.	υ Pegasi	+0.03	+0.06	− 0.13	22 06 08.76	22 03 59.95	2 08.81	−0.05	2 08.76
R.	θ Aquarii	+0.04	+0.05	− 0.13	22 12 29.79	22 10 20.92	2 08.87	−0.04	2 08.83
D.	γ Aquarii	+0.04	+0.08	+ 0.10	22 17 27.38	22 15 18.52	2 08.86	−0.04	2 08.82
D.	π Aquarii	+0.03	+0.12	+ 0.10	22 21 09.00	22 19 00.05	2 08.95	−0.04	2 08.91
D.	η Aquarii	+0.04	+0.12	+ 0.10	22 31 11.35	22 29 02.49	2 08.86	−0.03	2 08.83
D.	ζ Pegasi	+0.03	+0.11	+ 0.10	22 37 28.77	22 35 19.92	2 08.85	−0.03	2 08.82
D.	λ Pegasi	+0.02	+0.11	+ 0.11	22 42 45.48	22 40 36.71	2 08.77	−0.03	2 08.74
D.	μ Pegasi	+0.02	+0.12	+ 0.11	22 46 13.16	22 44 04.32	2 08.84	−0.03	2 08.81
D.	λ Aquarii	+0.04	+0.08	+ 0.10	22 48 21.16	22 46 12.38	2 08.88	−0.03	2 08.85
	Carr. 3525					22 55 22.50			
	Carr. 76					0 30 37.08			
D.	δ Piscium	+0.03	+0.07	+ 0.10	0 44 27.57	0 42 18.73	2 08.84	+0.04	2 08.88
D.	μ Andromedæ	+0.01	+0.13	+ 0.12	0 52 05.21	0 49 56.38	2 08.83	+0.04	2 08.87
D.	ε Piscium	+0.03	+0.08	+ 0.10	0 58 43.04	0 56 34.31	2 08.73	+0.04	2 08.77
D.	β Andromedæ	+0.01	+0.11	+ 0.12	1 05 00.23	1 02 51.54	2 08.69	+0.05	2 08.74
D.	τ Piscium	+0.01	+0.10	+ 0.11	1 07 02.81	1 04 54.01	2 08.80	+0.05	2 08.85
R.	υ Piscium	+0.02	+0.10	− 0.14	1 14 51.88	1 12 43.10	2 08.78	+0.05	2 08.83
R.	θ Ceti	+0.04	+0.06	− 0.13	1 20 02.15	1 17 53.40	2 08.75	+0.05	2 08.80
R.	η Piscium	+0.03	+0.11	− 0.13	1 27 03.62	1 24 54.74	2 08.88	+0.06	2 08.94
R.	ν Piscium	+0.03	+0.12	− 0.13	1 37 11.41	1 35 02.58	2 08.83	+0.06	2 08.89
R.	ο Piscium	+0.03	+0.10	− 0.13	1 41 03.45	1 38 54.71	2 08.74	+0.06	2 08.80
	Carr. 299					1 58 12.26			
	Mean								−2 08.837

From 1 Draconis, $c = +0^s.122$, tels. direct.
From Carr. 3525, $c = +0^s.112$, tels. direct.
From Carr. 76, $c = +0^s.112$, tels. direct.
From Carr. 299, $c = +0^s.150$, tels. direct.

Mean......$c = \pm 0^s.124$, { tels. direct. / tels. reversed.

$a = +0^s.101$
$a = +0^s.005$
$a = +0^s.062$
$a = +0^s.043$

Mean......$a = +0^s.053$

$c + \Delta\iota + abr = +0^s.098$, tels. direct.
$c + \Delta\iota + abr = -0^s.128$, tels. reversed.

$\Delta t_o = -2^m\,08^s.837$ at $23^h\,37^m$ clock-time.
$\rho = +\quad 0^s.031$

TABLE 17.—*Detroit, December 5, 1876.—Observer, H. M. Adams.*

Tels.	Stars.		Aa	Bb	C (c+Δι+abr.)	t'_0	α	Δt	rρ	Δ't
			s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
	α	Ursæ Minoris					1 13 51.04			
R.	β	Arietis	+0.01	+0.07	−0.17	1 50 00.37	1 47 51.62	−2 08.75	−0.06	−2 08.69
R.	γ	Andromedæ	+0.00	+0.10	−0.21	1 58 30.77	1 56 22.02	−2 08.75	−0.05	−2 08.70
R.	α	Arietis	+0.01	+0.07	−0.17	2 02 24.20	2 00 15.36	−2 08.84	−0.05	−2 08.79
R.	ξ¹	Ceti	+0.02	+0.06	−0.16	2 08 38.73	2 06 29.78	−2 08.95	−0.05	−2 08.90
R.	γ	Trianguli	+0.01	+0.07	−0.19	2 12 10.11	2 10 01.26	−2 08.85	−0.05	−2 08.80
R.	o	Ceti	+0.02	+0.04	−0.16	2 15 17.87	2 13 09.02	−2 08.85	−0.05	−2 08.80
D.	ξ¹	Ceti	+0.02	+0.06	+0.13	2 23 46.87	2 21 38.18	−2 08.69	−0.04	−2 08.65
D.	ι	Arietis	+0.01	+0.03	+0.13	2 33 59.57	2 31 51.08	−2 08.49	−0.04	−2 08.45
D.	γ	Ceti	+0.02	+0.01	+0.13	2 39 05.35	2 36 56.78	−2 08.57	−0.04	−2 08.53
D.	τ1	Arietis	+0.01	+0.02	+0.14	2 44 54.43	2 42 45.78	−2 08.65	−0.04	−2 08.61
D.		Eridani	+0.02	+0.02	+0.13	2 52 34.99	2 50 26.35	−2 08.64	−0.03	−2 08.61
D.		Ceti	+0.02	+0.02	+0.13	2 58 00.92	2 55 52.18	−2 08.74	−0.03	−2 08.71
		Carr. 491					3 26 37.10			
	ε	Ursæ Minoris, (L. C)					16 58 29.17			
R.	θ	Orionis	+0.02	+0.05	−0.16	5 10 47.67	5 08 39.01	−2 08.66	+0.02	−2 08.68
R.	τ	Orionis	+0.02	+0.06	−0.16	5 13 48.24	5 11 39.50	−2 08.74	+0.02	−2 08.76
R.	β	Tauri	+0.01	+0.06	−0.18	5 20 41.14	5 18 32.53	−2 08.61	+0.02	−2 08.63
R.	δ	Orionis	+0.02	+0.04	−0.16	5 27 53.42	5 25 44.77	−2 08.65	+0.02	−2 08.67
R.	φ¹	Orionis	+0.02	+0.05	−0.16	5 30 14.19	5 28 05.43	−2 08.76	+0.03	−2 08.79
R.	ε	Orionis	+0.02	+0.04	−0.16	5 32 08.35	5 29 59.71	−2 08.64	+0.03	−2 08.67
D.	130	Tauri	+0.01	+0.04	+0.13	5 42 25.91	5 40 17.26	−2 08.65	+0.03	−2 08.68
D.	ν	Aurigæ	0.00	+0.07	+0.16	5 45 08.27	5 42 59.54	−2 08.73	+0.03	−2 08.76
D.	α	Orionis	+0.02	+0.05	+0.13	5 50 40.63	5 48 32.14	−2 08.49	+0.03	−2 08.52
D.	υ	Aurigæ	+0.00	+0.13	+0.16	5 53 30.28	5 51 21.70	−2 08.58	+0.03	−2 08.61
D.	66	Orionis	+0.02	+0.08	+0.13	6 00 38.51	05 58 29.75	−2 08.76	+0.04	−2 08.80
	δ	Ursæ Minoris					18 11 37.95			
		Mean								−2 08.687

From α Urs. Minoris, $c = +0.139$ s., tels. direct.
From Carr. 491 $c = +0.187$, tels. direct.
From ε Urs. Minoris, $c = +0.110$, tels. direct.
From δ Urs. Minoris, $c = +0.069$, tels. direct.

Mean .... $c = \pm 0.126$, { tels. direct. / tels. reversed.

$c + \Delta\iota + abr = +0.126$, tels. direct.
$c + \Delta\iota + abr = -0.156$, tels. reversed.

$a = -0.016$ s.
$a = +0.042$
$a = +0.016$
$a = +0.080$

Mean.... $a = +0.030$

$\Delta t_0 = -2^m\ 08^s.687$ at $4^h\ 22^m$ clock-time.
$\rho = +\ 0.092$

TABLE 18.—*Detroit, December 19, 1876.—Observer, H. M. Adams.*

Tela.	Stars.	Aa	Bb	C (c+Δι+abr)	t_0'	a	Δt	rρ	Δt'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
	α Ursæ Minoris					1 13 40.71			
R.	β Arietis	+0.06	+0.15	−0.13	1 49 57.82	1 47 51.54	−2 06.28	−0.17	−2 06.11
R.	γ Andromedæ	+0.00	+0.20	−0.17	1 58 27.98	1 56 21.91	2 06.07	−0.17	2 05.90
R.	α Arietis	+0.05	+0.16	−0.14	2 02 21.45	2 00 15.29	2 06.16	−0.16	2 06.00
R.	ξ¹ Ceti	+0.08	+0.13	−0.13	2 08 36.12	2 06 29.71	2 06.41	−0.15	2 06.26
R.	γ Trianguli	+0.03	+0.18	−0.15	2 12 07.47	2 10 01.18	2 06.29	−0.15	2 06.14
R.	ο Ceti	+0.10	+0.11	−0.12	2 15 15.40	2 13 08.95	2 06.45	−0.15	2 06.30
D.	ξ² Ceti	+0.08	+0.13	+0.10	2 23 44.44	2 21 38.13	2 06.31	−0.14	2 06.17
D.	ν Ceti	+0.09	+0.12	+0.10	2 39 02.95	2 36 56.75	2 06.20	−0.12	2 06.08
D.	41 Arietis	+0.04	+0.17	+0.11	2 44 51.93	2 42 45.76	2 06.17	−0.11	2 06.06
D.	η Eridani	+0.11	+0.10	+0.10	2 52 32.56	2 50 26.32	2 06.24	−0.10	2 06.14
D.	α Ceti	+0.09	+0.12	+0.10	2 57 58.43	2 55 52.16	2 06.27	−0.10	2 06.17
	Carr 491					3 26 35.90			
R.	β Orionis	+0.11	+0.11	−0.13	5 10 45.27	5 08 39.16	2 06.11	+0.05	2 06.16
R.	τ Orionis	+0.11	+0.11	−0.13	5 13 45.82	5 11 39.65	2 06.17	+0.05	2 06.22
R.	β Tauri	+0.04	+0.19	−0.14	5 20 38.59	5 18 32.72	2 05.87	+0.06	2 05.93
R.	δ Orionis	+0.10	+0.13	−0.13	5 27 51.10	5 25 44.95	2 06.15	+0.07	2 06.22
R.	φ¹ Orionis	+0.08	+0.15	−0.13	5 30 11.82	5 28 05.63	2 06.19	+0.07	2 06.26
R.	ε Orionis	+0.10	+0.12	−0.13	5 32 06.10	5 29 59.88	2 06.22	+0.07	2 06.29
D.	130 Tauri	+0.06	+0.16	+0.10	5 42 23.44	5 40 17.49	2 05.95	+0.09	2 06.04
D.	ν Aurigæ	+0.01	+0.22	+0.12	5 45 05.70	5 42 59.82	2 05.88	+0.09	2 05.97
D.	α Orionis	+0.08	+0.11	+0.10	5 50 38.25	5 48 32.35	2 05.90	+0.09	2 05.99
D.	θ Aurigæ	+0.02	+0.22	+0.12	5 53 28.00	5 51 21.96	2 06.04	+0.10	2 06.14
D.	66 Orionis	+0.09	+0.11	+0.10	6 00 36.02	5 58 29.98	2 06.04	+0.11	2 06.15
	δ Ursæ Minoris, L. C					18 11 35.82			
	Mean								−2 06.123

From α Ursæ Minoris, $c = +0.170$ s., tels. direct.
From Carr. 491, $c = +0.153$, tels. direct.
From δ Ursæ Minoris, $c = +0.046$, tels. direct.

Mean.......... $c = \pm 0.123$, $\left\{ \begin{array}{l} \text{tels. direct.} \\ \text{tels. reversed.} \end{array} \right.$

$c + \Delta\iota + abr = +0.095$, tels. direct.
$c + \Delta\iota + abr = -0.125$, tels. reversed.

$a = +0.014$ s.
$a = +0.151$
$a = +0.262$

Mean .... $a = +0.142$

$\Delta t_0 = -2^m\ 06^s.123$ at $4^h\ 26^m$ clock-time.
$\rho = +\ 0^s.067$

TABLE 19.—*Detroit, March 10, 1877.—Observer, H. M. Adams.*

Tels.	Stars.	Aa	Bb	$C(c+\Delta i+abr)$	t_0^1	α	Δt	$r\rho$	Δt^1
		s.	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*s.*	*m. s.*
	δ Ursæ Minoris, L. C					18 11 48.91			
R.	γ Geminorum	−0.23	+0.01	0.00	6 33 03.14	6 30 37.92	−2 25.22	−0.02	−2 25.20
R.	15 Monocerotis	−0.28	+0.01	0.00	6 36 39.04	6 34 13.75	2 25.29	−0.02	2 25.27
R.	ε Geminorum	−0.17	+0.01	0.00	6 38 48.75	6 36 23.51	2 25.24	−0.02	2 25.22
R.	ξ Geminorum	−0.26	+0.01	0.00	6 40 49.93	6 38 24.65	2 25.28	−0.02	2 25.26
R.	18 Monocerotis	−0.33	+0.01	0.00	6 43 53.52	6 41 28.29	2 25.23	−0.02	2 25.21
R.	ν Geminorum	−0.09	+0.01	0.00	6 47 08.06	6 44 42.69	2 25.37	−0.02	2 25.35
D.	ζ Geminorum	−0.20	0.00	−0.04	6 59 15.72	6 56 50.52	2 25.20	−0.01	2 25.19
D.	63 Aurigæ	−0.03	+0.01	−0.04	7 05 38.96	7 03 13.74	2 25.22	−0.01	2 25.21
D.	λ Geminorum	−0.23	+0.02	−0.04	7 13 28.41	7 11 03.18	2 25.23	−0.01	2 25.22
D.	δ Geminorum	−0.19	+0.02	−0.04	7 15 13.68	7 12 48.47	2 25.21	−0.01	2 25.20
D.	ι Geminorum	−0.15	+0.03	−0.04	7 20 32.37	7 18 07.18	2 25.19	−0.01	2 25.18
D.	β Canis Minoris	−0.29	+0.02	−0.03	7 22 55.73	7 20 30.50	2 25.23	−0.01	2 25.22
	λ Ursæ Minoris, L. C					19 48 01.34			
	76 Draconis, L. C					20 51 11.23			
D.	κ Cancri	−0.28	+0.02	−0.03	9 03 32.37	9 01 07.18	2 25.19	+0.01	2 25.20
D.	θ Hydræ	−0.33	+0.02	−0.03	9 10 25.08	07 59.91	2 25.17	+0.01	2 25.18
D.	38 Lyncis	−0.06	+0.04	−0.04	9 13 39.14	11 13.89	2 25.25	+0.01	2 25.26
D.	40 Lyncis	−0.08	+0.03	−0.04	9 16 01.45	13 36.16	2 25.29	+0.01	2 25.30
D.	α Hydræ	−0.41	+0.02	−0.03	9 23 59.61	21 34.57	2 25.04	+0.01	2 25.05
D.	10 Leonis Minoris	−0.06	+0.04	−0.04	9 29 09.09	26 44.05	2 25.04	+0.01	2 25.05
R.	ο Leonis	−0.28	+0.04	0.00	9 37 02.55	34 37.29	2 25.26	+0.01	2 25.27
R.	ε Leonis	−0.18	+0.04	0.00	9 41 19.78	38 54.61	2 25.17	+0.01	2 25.18
R.	μ Leonis	−0.16	+0.05	0.00	9 48 13.76	45 48.45	2 25.31	+0.01	2 25.32
R.	19 Leonis Minoris	−0.01	+0.06	+0.01	9 52 37.16	50 11.86	2 25.30	+0.01	2 25.31
R.	π Leonis	−0.29	+0.04	0.00	9 56 10.29	53 44.98	2 25.21	+0.02	2 25.33
R.	η Leonis	−0.23	+0.04	0.00	10 03 05.13	10 00 39.87	2 25.26	+0.02	2 25.28
	30 Camelop					10 16 11.90			
	Mean								−2 25.229

From δ Ursæ Minoris, $c = -0.038$ s., tels. direct.
From λ Ursæ Minoris, $c = +0.020$, tels. direct.
From 76 Draconis, $c = -0.028$, tels. direct.
From 30 Camelopardalis, $c = +0.025$, tels. direct.

Mean .... $c = \mp 0.005$ s. { tels. direct. / tels. reversed.

March 10, $c = -0.005$ s., tels. direct.
March 19, $c = -0.015$, tels. direct.
March 28, $c = -0.002$, tels. direct.

Mean ... $c = \mp 0.007$ { tels. direct. / tels. reversed. } adopted for March 10, 19, and 28.

$c + \Delta i + abr = -0.034$ s., tels. direct.
$c + \Delta i + abr = +0.004$, tels. reversed.

$a = -0.650$ s.
$a = -0.460$
$a = -0.537$
$a = -0.438$

Mean .... $a = -0.521$

$\Delta t_0 = -2^m\ 25^s.228$ at $8^h\ 23^m$, clock-time.
$\rho = +\ 0^s.010$

TABLE 20.—*Detroit, March 19, 1877.—Observer, H. M. Adams.*

Tels.	Stars.	Aa	Bb	C(c+Δi+abr.)	t_0'	a	Δt	rρ	Δt'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
	δ Ursæ Minoris, L. C					18 11 52.23			
D.	γ Geminorum	−0.19	+0.13	−0.04	6 33 02.16	6 30 37.77	−2 24.39	−0.05	−2 24.34
D.	ε Geminorum	−0.13	+0.15	−0.04	6 38 47.79	6 36 23.35	−2 24.44	−0.04	−2 24.40
D.	ξ Geminorum	−0.21	+0.12	−0.04	6 40 48.94	6 38 24.50	−2 24.44	−0.04	−2 24.40
D.	18 Monocerotis	−0.26	+0.11	−0.03	6 43 52.67	6 41 28.14	−2 24.53	−0.04	−2 24.49
D.	θ Geminorum	−0.07	+0.16	−0.04	6 47 06.93	6 44 42.51	−2 24.42	−0.04	−2 24.38
R.	ζ Geminorum	−0.16	+0.14	0.00	6 59 14.69	6 56 50.37	−2 24.32	−0.04	−2 24.28
R.	83 Aurigæ	−0.02	+0.18	+0.01	7 05 37.94	7 03 13.55	−2 24.39	−0.04	−2 24.35
R.	λ Geminorum	−0.19	+0.13	0.00	7 13 27.42	7 11 03.04	−2 24.38	−0.03	−2 24.35
R.	δ Geminorum	−0.16	+0.14	0.00	7 15 12.66	7 12 48.33	−2 24.33	−0.03	−2 24.30
R.	ι Geminorum	−0.12	+0.16	+0.01	7 20 31.36	7 18 07.03	−2 24.33	−0.03	−2 24.30
R.	β Canis Minoris	−0.23	+0.12	0.00	7 22 54.82	7 20 30.37	−2 24.45	−0.03	−2 24.42
	λ Ursæ Minoris, L. C					19 46 10.40			
	76 Draconis, L. C					20 51 12.19			
R.	κ Cancri	−0.22	+0.08	0.00	9 03 31.48	9 01 07.11	−2 24.37	+0.02	−2 24.39
R.	θ Hydræ	−0.26	+0.07	0.00	9 10 24.19	9 07 59.85	−2 24.34	+0.02	−2 24.36
R.	38 Lyncis	−0.05	+0.12	+0.01	9 13 38.25	9 11 13.80	−2 24.45	+0.02	−2 24.47
R.	40 Lyncis	−0.07	+0.11	+0.01	9 16 00.37	9 13 36.09	−2 24.28	+0.02	−2 24.30
R.	α Hydræ	−0.32	+0.05	0.00	9 23 58.80	9 21 34.50	−2 24.30	+0.03	−2 24.33
R.	10 Leonis Minoris	−0.05	+0.16	+0.01	9 29 08.27	9 26 43.99	−2 24.28	+0.03	−2 24.31
D.	ο Leonis	−0.22	+0.10	−0.03	9 37 01.69	9 34 37.25	−2 24.44	+0.03	−2 24.47
D.	ε Leonis	−0.14	+0.12	−0.04	9 41 18.85	9 38 54.56	−2 24.29	+0.03	−2 24.32
D.	μ Leonis	−0.12	+0.13	−0.04	9 48 12.83	9 45 48.42	−2 24.41	+0.04	−2 24.45
D.	19 Leonis Minoris	−0.01	+0.17	−0.05	9 52 36.04	9 50 11.83	−2 24.21	+0.04	−2 24.25
D.	π Leonis	−0.23	+0.11	−0.04	9 56 09.36	9 53 44.98	−2 24.38	+0.04	−2 24.42
D.	η Leonis	−0.18	+0.13	−0.04	10 03 04.17	10 00 39.87	−2 24.30	+0.04	−2 24.34
	30 Camelop					10 16 11.38			
	Mean								−2 24.366

From δ Ursæ Minoris, $c = -0^s.027$, tels. direct.
From λ Ursæ Minoris, $c = +0.009$, tels. direct.
From 76 Draconis, $c = -0.023$, tels. direct.
From 30 Camelopardalis, $c = +0.041$, tels. direct.

Mean .... $c = \mp 0.015$ { tels. direct. / tels. reversed.

March 10, $c = -0^s.005$, tels. direct.
March 19, $c = -0.015$, tels. direct.
March 22, $c = -0.002$, tels. direct.

Mean... $c = \mp 0.007$ { tels. direct. / tels. reversed. } adopted for March 10, 19, and 22.

$c + \Delta i + abr = -0^s.034$, tels. direct.
$c + \Delta i + abr = +0.004$, tels. reversed.

$a = -0^s.400$
$a = -0.428$
$a = -0.436$
$a = -0.382$

Mean .... $a = -0.412$

$\Delta t_0 = -2^m\ 24^s.366$ at $8^h\ 23^m$, clock-time.
$\rho = +\ 0^s.0.5$

TABLE 21.—*Detroit, March 28, 1877.—Observer, H. M. Adams.*

Tels.	Stars.	Aa	Bb	C (c+Δi+a b r)	t'₀	α	Δt	rρ	Δt'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
	76 Draconis, (L. C.)					20 51 13.30			
R.	κ Cancri	+0.06	0.00	0.00	9 03 32.37	9 01 07.00	−2 25.37	0.03	−2 25.34
R.	θ Hydræ	+0.07	0.00	0.00	9 10 25.13	9 07 59.76	2 25.37	−0.02	2 25.35
R.	38 Lyncis	+0.01	0.00	+0.01	9 13 39.15	9 11 13.69	2 25.46	−0.02	2 25.44
R.	40 Lyncis	+0.02	0.00	0.00	9 16 01.42	9 13 35.98	2 25.44	−0.02	2 25.43
R.	α Hydræ	+0.08	−0.01	0.00	9 23 59.70	9 21 34.41	2 25.29	−0.02	2 25.27
D.	10 Leonis minoris	+0.01	−0.03	+0.01	9 29 09.13	9 26 43.89	2 25.24	−0.02	2 25.22
D.	ο Leonis	+0.06	+0.02	−0.03	9 37 02.65	9 34 37.18	2 25.47	−0.02	2 25.45
D.	ε Leonis	+0.04	+0.02	−0.04	9 41 09.76	9 38 54.47	2 25.29	−0.02	2 25.27
D.	μ Leonis	+0.03	+0.02	−0.04	9 48 13.74	9 45 48.39	2 25.35	−0.01	2 25.34
D.	19 Leonis minoris	0.00	+0.01	−0.05	9 52 37.08	9 50 11.74	2 25.34	−0.01	2 25.33
D.	π Leonis	+0.06	0.00	−0.03	9 56 10.29	9 53 44.93	2 25.36	−0.01	2 25.35
	η Leonis	+0.05	−0.01	−0.04	10 03 05.18	10 00 39.81	2 25.37	−0.01	2 25.36
	30 Camelop.					10 16 10.68			
	Carr, (3525, L. C)					22 55 03.18			
D.	δ Leonis	+0.04	−0.01	−0.04	11 10 01.76	11 07 36.58	2 25.19	+0.01	2 25.20
D.	ξ Urs. Maj. Med	+0.02	−0.01	−0.04	11 14 05.30	11 11 39.83	2 25.47	+0.01	2 25.48
D.	ο Leonis	+0.06	−0.01	−0.03	11 17 15.30	11 14 49.92	2 25.38	+0.01	2 25.39
D.	ι Leonis	+0.06	−0.01	−0.03	11 19 58.49	11 17 33.10	2 25.39	+0.01	2 25.40
D.	τ Leonis	+0.07	−0.01	−0.03	11 24 04.37	11 21 39.05	2 25.32	+0.01	2 25.33
D.	υ Leonis	+0.07	−0.01	−0.03	11 33 06.73	11 30 41.40	2 25.33	+0.02	2 25.35
R.	β Leonis	+0.05	−0.00	0.10	11 45 14.89	11 42 49.62	2 25.27	+0.02	2 25.29
R.	β Virginis	+0.07	0.00	0.10	11 46 45.04	11 44 19.59	2 25.45	+0.02	2 25.47
R.	ο Virginis	+0.06	0.00	0.00	12 01 24.28	11 58 59.07	2 25.21	+0.02	2 25.23
R.	2 Can. Ven	0.00	+0.01	+0.01	12 12 26.13	12 10 00.79	2 25.34	+0.03	2 25.37
R.	η Virginis	+0.07	0.00	0.00	12 16 04.49	12 13 39.16	2 25.33	+0.03	2 25.36
R.	6 Can. Ven	+0.01	+0.01	+0.01	12 22 15.74	12 19 50.39	2 25.35	+0.03	2 25.38
R.	20 Comæ	+0.04	0.00	0.00	12 26 00.41	12 23 35.23	2 25.18	+0.03	2 25.21
R.	32 Camelop					12 48 32.50			
	Mean								−2 25.344

From 76 Draconis, $c = +0.039$ s, tels. direct.
From 30 Camelop. $c = -0.005$, tels. direct.
From Carr. 3525, $c = -0.005$, tels. direct.
From 32 Camelop. $c = -0.035$, tels. direct.

Means .... $c = \mp 0.002$, { tels. direct. / tels. reversed.

March 10 $c = -0.005$ s.
March 19 $c = -0.015$.
March 28 $c = -0.002$.

Mean $c = \mp 0.007$, { tels. direct. / tels. reversed. } adopted for March 10, 19 and 28.

$c + \Delta i + a\,b\,r - 0.034$, tels. direct.
$c + \Delta i + a\,b\,r + 0.004$, tels. reversed.

$a = +0.114$ s.
$a = +0.110$.
$a = +0.161$.
$a = +0.053$.

Mean $a = +0.110$.
$\Delta t_0 = -2^m\ 25^s.344$ at $10^h\ 36^m$ clock-time.
$\rho = +0.017$.

TABLE 22.—*Relative personal equation—H. M. Adams and D. W. Lockwood, 1876.*

Signals from—	Date.	Clock No. 236—Adams, observer. Means of clock times of comparisons.	Clock corrections.	Means of sidereal times of comparisons.	Chronometer No. 1524—Lockwood, observer. Means of chronometer times of comparisons	Chronometer corrections.	Means of sidereal times of comparisons.	Differences of time. Signals from clock.	Signals from chronometer.	Means.
	1876.	h. m. s.	m. s.	h. m. s.	h. m. s.	m. s.	h. m. s.	s.	s.	s.
Clock	July 15	17 36 08.000	−1 36.474	17 34 31.526	17 35 45.577	−1 13.811	17 34 31.766	−0.240		
Clock	July 15	17 36 23.000	1 36.474	17 34 46.526	17 36 00.579	1 13.811	17 34 46.768	−0.242		
Clock	July 15	17 36 38.000	1 36.474	17 35 01.526	17 36 15.581	1 13.811	17 35 01.770	−0.244		
Clock	July 15	17 36 57.000	1 36.474	17 35 20.526	17 36 34.584	1 13.811	17 35 20.773	−0.247		
Chronometer	July 15	17 37 59.475	1 36.474	17 36 23.001	17 37 37.000	1 13.811	17 36 23.189	....	−0.188	
Chronometer	July 15	17 38 43.476	1 36.474	17 37 07.002	17 38 21.000	1 13.811	17 37 07.189	....	−0.187	
Chronometer	July 15	17 39 30.478	1 36.474	17 37 54.004	17 39 08.000	1 13.811	17 37 54.189	....	−0.185	
Chronometer	July 15	17 40 14.479	1 36.475	17 38 38.004	17 39 52.000	1 13.811	17 38 38.189	....	−0.185	
Means for July 15	....	....	....	....	....	....	....	−0.243	−0.186	−0.215
Clock	July 18	17 36 24.000	−1 37.993	17 34 46.007	17 36 08.415	−1 22.208	17 34 46.206	−0.199		
Clock	July 18	17 36 45.000	1 37.993	17 35 07.007	17 36 29.408	1 22.209	17 35 07.199	−0.192		
Clock	July 18	17 37 08.000	1 37.993	17 35 30.007	17 36 52.408	1 22.209	17 35 30.199	−0.192		
Clock	July 18	17 37 59.000	1 37.994	17 36 21.006	17 37 43.409	1 22.208	17 36 21.201	−0.195		
Chronometer	July 18	17 39 23.627	1 37.994	17 37 45.633	17 39 04.000	1 22.207	17 37 45.793	....	−0.160	
Chronometer	July 18	17 39 56.628	1 37.994	17 38 18.634	17 39 41.000	1 22.207	17 38 18.793	....	−0.159	
Chronometer	July 18	17 40 30.627	1 37.994	17 38 52.633	17 40 15.000	1 22.207	17 38 52.793	....	−0.160	
Chronometer	July 18	17 41 07.628	1 37.995	17 39 29.633	17 40 52.000	1 22.207	17 39 29.793	....	−0.160	
Means for July 18	....	....	....	....	....	....	....	−0.195	−0.160	−0.178
Clock	Oct. 23	23 07 08.000	−2 09.816	23 04 58.184	23 04 16.219	+0 42.285	23 04 58.504	−0.320		
Clock	Oct. 23	23 09 08.000	2 09.816	23 06 58.184	23 06 16.212	0 42.283	23 06 58.495	−0.311		
Chronometer	Oct. 23	23 15 21.849	2 09.814	23 13 12.035	23 12 30.000	0 42.279	23 13 12.279	....	−0.244	
Chronometer	Oct. 23	23 17 33.849	2 09.813	23 15 24.036	23 14 42.000	0 42.277	23 15 24.277	....	−0.241	
Clock	Oct. 23	23 19 08.000	2 09.813	23 16 58.187	23 16 16.229	0 42.276	23 16 58.505	−0.318		
Clock	Oct. 23	23 23 08.000	2 09.811	23 20 58.189	23 20 16.227	0 42.273	23 20 58.500	−0.311		
Chronometer	Oct. 23	23 25 08.835	2 09.811	23 22 59.024	23 22 17.000	0 42.271	23 22 59.271	....	−0.247	
Chronometer	Oct. 23	23 28 20.833	2 09.810	23 26 11.023	23 25 29.000	0 42.269	23 26 11.269	....	−0.246	
Means for October 23	....	....	....	....	....	....	....	−0.315	−0.245	−0.280

	s.
Mean for July 15 and 18, and October 23	−0.224
Correction for difference of longitude of transit instruments	−0.005
Lockwood observes earlier than Adams	−0.229

TABLE 23.

TELEGRAPHIC LONGITUDE, 1876.

Detroit, Michigan—Mount Forest, Illinois.

Signals from—	Date.	Detroit. Means of clock times of comparisons.	Detroit. Clock corrections.	Detroit. Means of sidereal times of comparisons.	Mount Forest. Means of chronometer times of comparisons.	Mount Forest. Chronometer corrections.	Mount Forest. Means of sidereal times of comparisons.	Differences of times. Signals from Detroit.	Differences of times. Signals from Mount Forest.	Differences of times. Means.
	1876.	h. m. s.	m. s.	h. m. s.	h. m. s.	m. s.	h. m. s.	m. s.	m. s.	m. s.
Detroit	Aug. 17	20 35 14.000	—1 51.509	20 33 22.491	20 33 14.161	—19 06.600	20 14 07.561	19 14.930	....	
Detroit	Aug. 17	20 35 50.000	1 51.509	20 33 58.491	20 33 50.160	19 06.601	20 14 43.559	19 14.932	....	
Detroit	Aug. 17	20 50 14.000	1 51.513	20 48 22.487	20 48 14.145	19 06.611	20 29 07.534	19 14.953	....	
Detroit	Aug. 17	20 50 50.000	1 51.513	20 48 58.487	20 48 50.140	19 06.612	20 29 43.528	19 14.959	....	
Mount Forest	Aug. 17	20 53 45.026	1 51.513	20 51 53.513	20 51 45.000	19 06.614	20 32 38.386	....	19 15.127	
Mount Forest	Aug. 17	20 55 05.028	1 51.514	20 53 13.514	20 53 05.000	19 06.615	20 33 58.385	....	19 15.129	
Mount Forest	Aug. 17	20 59 20.024	1 51.515	20 57 28.509	20 57 20.000	19 06.618	20 38 13.382	....	19 15.127	
Mount Forest	Aug. 17	20 59 50.027	1 51.515	20 57 58.512	20 57 50.000	19 06.619	20 38 43.381	....	19 15.131	
Means for August 17	....	....	....	....	....	....	....	19 14.944	19 15.128	19 15.036
Detroit	Aug. 23	20 30 20.000	—1 54.028	20 28 25.972	20 28 13.479	—19 02.516	20 09 10.963	19 15.009	....	
Detroit	Aug. 23	20 30 52.000	1 54.028	20 28 57.972	20 28 45.484	19 02.516	20 09 42.968	19 15.004	....	
Mount Forest	Aug. 23	20 41 14.709	1 54.031	20 39 20.678	20 39 08.000	19 02.518	20 20 05.482	....	19 15.196	
Detroit	Aug. 23	20 44 52.000	1 54.032	20 42 57.968	20 42 45.449	19 02.518	20 23 42.931	19 15.037	....	
Detroit	Aug. 23	20 45 52.000	1 54.032	20 43 57.968	20 43 45.445	19 02.519	20 24 42.926	19 15.043	....	
Mount Forest	Aug. 23	20 47 14.732	1 54.032	20 45 20.700	20 45 08.000	19 02.519	20 26 05.481	....	19 15.219	
Mount Forest	Aug. 23	20 51 14.741	1 54.033	20 49 20.708	20 49 08.000	19 02.519	20 30 05.481	....	19 15.227	
Mount Forest	Aug. 23	20 53 14.736	1 54.434	20 51 20.702	20 51 08.000	19 02.520	20 32 05.480	....	19 15.222	
Means for August 23	....	....	....	....	....	....	....	19 15.023	19 15.216	19 15.120
Detroit	Aug. 25	21 50 04.000	—1 55.195	21 48 08.805	21 47 54.588	—19 00.817	21 28 53.771	19 15.034	....	
Detroit	Aug. 25	21 50 32.000	1 55.195	21 48 36.805	21 48 22.585	19 00.817	21 29 21.768	19 15.037	....	
Mount Forest	Aug. 25	21 54 17.649	1 55.197	21 52 22.452	21 52 08.000	19 00.813	21 33 07.187	....	19 15.265	
Detroit	Aug. 25	22 03 27.000	1 55.203	22 01 31.797	22 01 17.565	19 00.804	21 43 16.761	19 15.036	....	
Detroit	Aug. 25	22 04 52.000	1 55.204	22 02 56.796	22 02 42.560	19 00.802	21 43 41.758	19 15.038	....	
Mount Forest	Aug. 25	22 06 17.632	1 55.205	22 04 22.427	22 04 08.000	19 00.801	21 45 07.199	....	19 15.228	
Mount Forest	Aug. 25	22 10 17.635	1 55.208	22 08 22.427	22 08 08.000	19 00.797	21 49 07.203	....	19 15.224	
Mount Forest	Aug. 25	22 12 17.631	1 55.209	22 10 22.422	22 10 08.000	19 00.795	21 51 07.205	....	19 15.217	
Means for August 25	....	....	....	....	....	....	....	19 15.036	19 15.231	19 15.135

Detroit	Aug. 26	21 47 52.000	−1 55.548	21 45 56.452	21 45 41.749	−19 00.258	21 26 41.491	19 14.961	....	
Detroit	Aug. 26	21 48 52.000	1 55.548	21 46 56.452	21 46 41.745	19 00.258	21 27 41.487	19 14.965	....	
Mount Forest	Aug. 26	21 52 18.423	1 55.549	21 50 22.874	21 50 08.000	19 00.257	21 31 07.743	....	19 15.131	
Mount Forest	Aug. 26	21 54 18.437	1 55.549	21 52 22.888	21 52 08.000	19 00.256	21 33 07.744	....	19 15.144	
Detroit	Aug. 26	21 56 52.000	1 55.550	21 54 56.450	21 54 41.745	19 00.255	21 35 41.490	19 14.960	....	
Detroit	Aug. 26	21 57 52.000	1 55.550	21 55 56.450	21 55 41.738	19 00.255	21 36 41.483	19 14.967	....	
Mount Forest	Aug. 26	21 59 18.430	1 55.551	21 57 22.899	21 57 08.000	19 00.254	21 38 07.746	....	19 15.153	
Mount Forest	Aug. 26	22 03 18.435	1 55.552	22 03 22.883	22 03 08.000	19 00.252	21 44 07.748	....	19 15.135	
Means for August 26	....	....	....	....	....	....	....	19 14.963	19 15.141	19 15.052

Means for August 17 23, 25, and 26	19 15.086
Relative personal equation. Adams—Lockwood	0.229
Mount Forest, Ill., west of Detroit, Mich	19 15.315

TABLE 24.

TELEGRAPHIC LONGITUDE 1876.

Detroit—Saginaw, Mich.

Signals from—	Date.	Detroit. Means of clock times of comparisons.	Detroit. Clock corrections.	Detroit. Means of sidereal times of comparisons.	Saginaw. Means of chronometer times of comparisons.	Saginaw. Chronometer corrections.	Saginaw. Means of sidereal times of comparison.	Differences of times. Signals from Detroit.	Differences of times. Signals from Saginaw.	Differences of times. Means.
	1876.	h. m. s.	m. s.	h. m. s.	h. m. s.	m. s.	h. m. s.	m. s.	m. s.	m. s.
Detroit	Sept. 12	21 35 30.000	−2 01.547	21 33 28.453	21 33 08.697	−3 18.933	21 29 49.764	3 38.689	....	
Detroit	Sept. 12	21 36 30.000	2 01.547	21 34 28.453	21 34 08.696	3 18.932	21 30 49.764	3 38.689	....	
Saginaw	Sept. 12	21 38 29.377	2 01.548	21 36 27.829	21 36 08.000	3 18.930	21 32 49.070	....	3 38.759	
Saginaw	Sept. 12	21 40 29.379	2 01.548	21 38 27.831	21 38 08.000	3 18.927	21 34 49.073	....	3 38.758	
Detroit	Sept. 12	21 42 30.000	2 01.548	21 40 28.452	21 40 08.675	3 18.925	21 36 49.750	3 38.702	....	
Detroit	Sept. 12	21 43 30.000	2 01.548	21 41 28.452	21 41 08.679	3 18.924	21 37 49.755	3 38.697	....	
Saginaw	Sept. 12	21 45 29.396	2 01.549	21 43 27.847	21 43 08.000	3 18.921	21 39 49.079	....	3 38.768	
Saginaw	Sept. 12	21 47 29.399	2 01.549	21 45 27.850	21 45 08.000	3 18.919	21 41 49.081	....	3 38.769	
Means for September 12	....	....	....	....	....	....	....	3 38.694	3 38.764	3 38.729
Detroit	Sept. 16	21 34 38.000	−2 02.720	21 32 35.280	21 32 08.665	−3 12.089	21 28 56.576	3 38.704	....	
Detroit	Sept. 16	21 35 38.000	2 02.720	21 33 35.280	21 33 08.665	3 12.087	21 29 56.578	3 38.702	....	
Saginaw	Sept. 16	21 37 37.407	2 02.721	21 35 34.686	21 35 08.000	3 12.082	21 31 55.918	....	3 38.768	
Saginaw	Sept. 16	21 43 37.441	2 02.723	21 41 34.718	21 41 08.000	3 12.070	21 37 55.930	....	3 38.788	
Detroit	Sept. 16	21 46 38.000	2 02.724	21 44 35.276	21 44 08.619	3 12.063	21 40 56.556	3 38.720	....	
Detroit	Sept. 16	21 47 38.000	2 02.725	21 45 35.275	21 45 08.616	3 12.061	21 41 56.555	3 38.720	....	
Saginaw	Sept. 16	21 49 37.447	2 02.725	21 47 34.722	21 47 08.000	3 12.057	21 43 55.943	....	3 38.779	
Saginaw	Sept. 16	21 51 37.449	2 02.726	21 49 34.723	21 49 08.000	3 12.053	21 45 55.947	....	3 38.776	
Means for September 16	....	....	....	....	....	....	....	3 38.712	3 38.778	3 38.745
Means for September 12 and 16										3 38.737
Relative personal equation. Adams—Lockwood										0.229
Saginaw west of Detroit, Mich										3 38.966

TABLE 25.

TELEGRAPHIC LONGITUDE.

Detroit—Saint Louis, Michigan.

Signals from—	Date.	Detroit.			Saint Louis.			Differences of times.		
		Means of clock times of comparisons.	Clock corrections.	Means of sidereal times of comparisons.	Means of chronometer times of comparisons.	Chronometer corrections.	Means of sidereal times of comparisons.	Signals from Detroit.	Signals from Saint Louis.	Means.
	1876.	*h. m. s.*	*m. s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*h. m. s.*	*m. s.*	*m. s.*	*m. s.*
Detroit	Oct. 11	23 27 08.000	—2 08.981	23 24 59.019	23 24 00.000	5 13.354	23 18 46.646	6 12.373		
Detroit	Oct. 11	23 28 35.000	2 08.981	23 26 26.019	23 25 27.000	5 13.352	23 20 13.648	6 12.371		
Saint Louis	Oct. 11	23 32 28.107	2 08.979	23 30 19.128	23 29 20.000	5 13.346	23 24 06.654		6 12.474	
Saint Louis	Oct. 11	23 49 28.101	2 08.971	23 47 19.130	23 46 20.000	5 13.319	23 41 06.681		6 12.449	
Saint Louis	Oct. 11	23 55 28.105	2 08.969	23 53 19.136	23 52 20.000	5 13.310	23 47 06.690		6 12.446	
Detroit	Oct. 11	0 04 08.000	2 08.965	0 01 59.035	0 01 00.000	5 13.296	23 55 46.704	6 12.331		
Detroit	Oct. 11	0 04 52.000	2 08.964	0 02 43.036	0 01 44.000	5 13.295	23 56 30.705	6 12.332		
Saint Louis	Oct. 11	0 08 28.119	2 08.963	0 06 19.156	0 05 20.000	5 13.289	0 00 06.711		6 12.445	
Means for October 11								6 12.352	6 12.454	6 12.403
Detroit	Oct. 12	23 18 18.000	—2 08.847	23 16 09.153	23 15 08.527	5 11.621	23 09 56.906	6 12.247		
Detroit	Oct. 12	23 19 18.000	2 08.846	23 17 09.154	23 16 08.526	5 11.621	23 10 56.905	6 12.249		
Saint Louis	Oct. 12	23 23 17.530	2 08.844	23 21 08.686	23 20 08.000	5 11.622	23 14 56.378		6 12.303	
Saint Louis	Oct. 12	23 29 17.536	2 08.841	23 27 08.695	23 26 08.000	5 11.623	23 20 56.377		6 12.318	
Detroit	Oct. 12	23 32 18.000	2 08.839	23 30 09.161	23 29 08.534	5 11.624	23 23 56.910	6 12.251		
Detroit	Oct. 12	23 33 18.000	2 08.839	23 31 09.161	23 30 08.536	5 11.624	23 24 56.912	6 12.249		
Saint Louis	Oct. 12	23 45 17.541	2 08.833	23 43 08.708	23 42 08.000	5 11.627	23 36 56.373		6 12.335	
Saint Louis	Oct. 12	23 47 17.546	2 08.832	23 45 08.714	23 44 08.000	5 11.627	23 38 56.373		6 12.341	
Means for October 12								6 12.249	6 12.326	6 12.288
Means for October 11 and 12										6 12.346
Relative personal equation. Adams—Lockwood										0.229
Saint Louis west of Detroit, Mich										6 12.575

TABLE 26.

TELEGRAPHIC LONGITUDE.

Detroit, Mich.—Cairo, Ill.

Signals from—	Date.	Detroit.			Cairo.			Differences of times.		
		Means of clock times of comparisons.	Clock corrections.	Means of sidereal times of comparisons.	Means of chronometer times of comparisons.	Chronometer corrections.	Means of sidereal times of comparisons.	Signals from Detroit.	Signals from Cairo.	Means.
	1876.	h. m. s.	m. s.	h. m. s.	h. m. s.	m. s.	h. m. s.	m. s.	m. s.	m. s.
Detroit	Dec. 5	4 12 08.000	−2 08.691	4 09 59.309	4 10 20.422	−24 46.654	3 45 33.762	24 25.541	....	
Detroit	Dec. 5	4 14 08.000	2 08.690	4 11 59.310	4 12 20.434	24 46.653	3 47 33.781	24 25.529	....	
Cairo	Dec. 5	4 16 08.809	2 08.689	4 14 00.120	4 14 21.000	24 46.651	3 49 34.349	....	24 25.771	
Cairo	Dec. 5	4 22 08.800	2 08.687	4 20 00.113	4 20 21.000	24 46.647	3 45 34.353	....	24 25.760	
Detroit	Dec. 5	4 26 39.000	2 08.685	4 24 30.315	4 24 51.423	24 46.644	4 00 04.779	24 25.536	....	
Detroit	Dec. 5	4 27 08.000	2 08.685	4 24 59.315	4 25 20.433	24 46.643	4 00 33.790	24 25.525	....	
Cairo	Dec. 5	4 39 08.813	2 08.681	4 37 00.132	4 37 21.000	24 46.635	4 12 34.365	....	24 25.767	
Cairo	Dec. 5	4 40 39.819	2 08.680	4 38 31.139	4 38 52.000	24 46.634	4 14 05.366	....	24 25.773	
Means for December 5	....	....	....	....	....	....	....	24 25.533	24 25.768	24 25.650
Detroit	Dec. 19	4 09 22.500	−2 06.142	4 07 16.358	4 07 24.410	−24 33.727	3 42 50.683	24 25.675	....	
Detroit	Dec. 19	4 10 32.000	2 06.140	4 08 25.860	4 08 33.903	24 33.726	3 44 00.177	24 25.683	....	
Cairo	Dec. 19	4 28 12.301	2 06.121	4 26 06.180	4 26 14.000	24 33.714	4 01 40.286	....	24 25.894	
Cairo	Dec. 19	4 29 12.303	2 06.119	4 27 06.184	4 27 14.000	24 33.713	4 02 40.287	....	24 25.807	
Detroit	Dec. 19	4 32 34.667	2 06.116	4 30 28.551	4 30 36.607	24 33.711	4 06 02.896	24 25.655	....	
Detroit	Dec. 19	4 37 41.750	2 06.110	4 35 35.640	4 35 43.672	24 33.707	4 11 09.965	24 25.675	....	
Cairo	Dec. 19	4 42 12.321	2 06.105	4 40 06.216	4 40 14.000	24 33.704	4 15 40.256	....	24 25.920	
Cairo	Dec. 19	4 44 12.319	2 06.103	4 42 06.216	4 42 14.000	24 33.702	4 17 40.298	....	24 25.918	
Means for December 19	....	....	....	....	....	....	....	24 25.672	24 25.907	24 25.790
Mean for December 5 and 19										24 25.720
Relative personal equation. Adams—Lockwood										0.146
Cairo, Ill., west of Detroit, Mich										24 25.866

TABLE 27.—*Relative personal equation, H. M. Adams and D. W. Lockwood*, 1877.

Signals from—	Date.	Clock No. 256—Adams, observer. Means of clock-times of comparisons.	Clock corrections.	Means of sidereal times of comparisons.	Chronometer No. 1524—Lockwood, observer. Means of chronometer-times of comparisons.	Chronometer corrections.	Means of sidereal times of comparisons.	Differences of times. Signals from clock.	Signals from chronometer.	Means.
	1877.	h. m. s.	m. s.	h. m. s.	h. m. s.	m. s.	h. m. s.	s.	s.	s.
Clock	Mar. 10	8 16 09.000	−2 25.229	8 13 43.771	8 19 19.509	−5 35.642	8 13 43.867	−0.096	....	
Clock	Mar. 10	8 18 09.000	2 25.229	8 15 43.771	8 21 19.505	5 35.636	8 15 43.869	−0.098	....	
Chronometer	Mar. 10	8 19 41.600	2 25.229	8 17 16.371	8 22 52.000	5 35.631	8 17 16.369	....	+0.002	
Chronometer	Mar. 10	8 21 41.600	2 25.228	8 19 16.372	8 24 52.000	5 35.625	8 19 16.375	....	−0.003	
Clock	Mar. 10	8 24 09.000	2 25.228	8 21 43.772	8 27 19.493	5 35.617	8 21 43.876	−0.104	....	
Clock	Mar. 10	8 26 09.000	2 25.227	8 23 43.773	8 29 19.485	5 35.610	8 23 43.875	−0.102	....	
Chronometer	Mar. 10	8 27 41.593	2 25.227	8 25 16.366	8 30 52.000	5 35.605	8 25 16.395	....	−0.029	
Chronometer	Mar. 10	8 29 41.600	2 25.227	8 27 16.373	8 32 52.000	5 35.599	8 27 16.401	....	−0.028	
Means for March 10	....	....	....	....	....	....	....	−0.100	−0.014	−0.057
Clock	Mar. 19	8 18 26.000	−2 24.368	8 16 01.632	8 21 10.965	−5 09.335	8 16 01.630	+0.002	....	
Clock	Mar. 19	8 18 59.000	2 24.368	8 16 34.632	8 21 43.967	5 09.334	8 16 34.633	−0.001	....	
Chronometer	Mar. 19	8 23 23.101	2 24.366	8 19 58.735	8 25 08.000	5 09.325	8 19 58.675	....	+0.060	
Chronometer	Mar. 19	8 24 23.105	2 24.365	8 21 58.740	8 27 08.000	5 09.319	8 21 58.681	....	+0.059	
Clock	Mar. 19	8 26 14.000	2 24.365	8 23 49.635	8 28 58.942	5 09.315	8 23 49.627	+0.008	....	
Clock	Mar. 19	8 26 39.000	2 24.364	8 24 14.636	8 29 23.953	5 09.314	8 24 14.639	−0.003	....	
Chronometer	Mar. 19	8 30 23.101	2 24.363	8 27 58.741	8 33 08.000	5 09.304	8 27 58.696	....	+0.045	
Chronometer	Mar. 19	8 32 23.112	2 24.362	8 29 58.750	8 35 08.000	5 09.299	8 29 58.701	....	+0.049	
Means for March 19	....	....	....	....	....	....	....	+0.002	+0.053	+0.028
Clock	Mar. 28	10 27 52.000	−2 25.346	10 25 26.654	10 30 10.763	−4 43.932	10 25 26.831	−0.177	....	
Clock	Mar. 28	10 29 52.000	2 25.346	10 27 26.654	10 32 10.781	4 43.929	10 27 26.852	−0.198	....	
Chronometer	Mar. 28	10 34 08.300	2 25.345	10 31 42.955	10 36 27.000	4 43.924	10 31 43.076	....	−0.121	
Chronometer	Mar. 28	10 36 08.300	2 25.344	10 33 42.956	10 38 27.000	4 43.922	10 33 43.078	....	−0.122	
Clock	Mar. 28	10 37 52.000	2 25.343	10 35 26.657	10 40 10.747	4 43.920	10 35 26.827	−0.170	....	
Clock	Mar. 28	10 39 52.000	2 25.343	10 37 26.657	10 42 10.739	4 43.917	10 37 26.822	−0.165	....	
Chronometer	Mar. 28	10 42 08.312	2 25.342	10 39 42.970	10 44 27.000	4 43.914	10 39 43.086	....	−0.116	
Chronometer	Mar. 28	10 43 08.315	2 25.342	10 40 42.973	10 45 27.000	4 43.913	10 40 43.087	....	−0.114	
Means for March 28	....	....	....	....	....	....	....	−0.178	−0.118	−0.148
Means for March 10, 19, and 28										−0.059
Correction for difference of longitude of transit instruments										−0.005
Lockwood observes earlier than Adams										0.164
Adopted value for 1876, (see Table 22)										0.229
Mean to be applied to longitude of Cairo										0.146

APPENDIX D.—ASTRONOMICAL WORK.

REPORT OF LIEUTENANT D. W. LOCKWOOD, CORPS OF ENGINEERS.

DETROIT, *Mich.*, *May* 7, 1877.

SIR: I have the honor to make the following report of work done by myself and under my charge during last season:

Acting under verbal instructions, I was engaged during a part of the month of July in taking time-observations for personal equation between Captain Adams and myself. On July 26 I received instructions to occupy the following stations, to determine the difference of longitude between them and Detroit observatory, viz: Station Willow Springs, Ill.; Saginaw, Saint Louis, Farwell, Midland, Hersey, and Big Rapids, Mich. At all the stations in Michigan two nights' observations for latitude were to be taken, and at Willow Springs, Saginaw, Saint Louis, and Midland the magnetic elements were to be determined; afterward I was ordered to occupy Cairo, Ill., for difference of longitude, and latitude. The following is a summary of the season's time-work. All observations at Detroit were for personal equation.

Detroit, July 15 and 18, 1876.
Mount Forest, (near Willow Springs,) August 17, 23, 25, and 26.
Saginaw, September 12 and 16.
Saint Louis, October 11 and 12.
Detroit, October 23.
Cairo, December 5 and 19.
Detroit, March 10, 19, and 28, 1877.

The instruments used for time-work were as follows: Würdemann astronomical transit No. 1, focal length 31 inches, 2½ inches object-glass, Negus break-circuit sidereal chronometer No. 1524, and Bond & Son's chronograph No. 245. The methods of recording time sending and receiving signals were the same as followed at the observatory at Detroit. The work on the nights of July 15 and 18, August 17, 23, 25, and 26, was reduced by the method of least squares. The high and low star method of reduction was adopted for the remainder of the season. Tables giving individual results, &c., for each night are appended hereto. The same system of notation in making them up is used as given by Captain Adams.

Observations for latitude were taken at Saginaw, Saint Louis, and Cairo; the instrument used being Würdemann zenith-telescope No. 19. The results at the different stations are appended hereto.

At Cairo, Ill., observations were taken to determine the azimuth of the line, Station Defiance–Station Ohio. The azimuth-post was carefully located on the line of the two stations. Appended to this will be found the results on the different nights.

Very respectfully,

D. W. LOCKWOOD,
First Lieutenant of Engineers.

MAJ. C. B. COMSTOCK,
Corps of Engineers.

Detroit, Michigan, July 15, 1876.—Observer, D. W. Lockwood.

Cl.	Stars.	A a	B b	C(Δi + a b r ∧ c.	r ρ	t'	a	Δ t'	p
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
E.	Carr. 580, L. C	−0.68	−0.17	− 0.29	+0.02	16 00 51.77	3 59 37.21	−1 14.56	0.045
W.	Carr. 580, L. C	−0.66	−0.05	+ 0.59	+0.02	16 00 50.48	3 59 37.21	−1 13.27	0.045
W.	ε Ophiuchi	−0.07	+0.02	− 0.09	+0.01	16 13 02.22	16 11 48.41	−1 13.81	1.0
W.	γ Herculis	−0.04	+0.02	− 0.10	+0.01	16 17 43.42	16 16 29.63	−1 13.79	1.0
W.	ω Herculis	−0.04	+0.01	− 0.09	+0.01	16 20 58.00	16 19 44.17	−1 13.83	1.0
W.	β Herculis	−0.03	+0.01	− 0.10	+0.01	16 26 09.77	16 24 56.04	−1 13.73	1.0
W.	ζ Herculis	−0.02	+0.03	− 0.11	+0.01	16 37 51.04	16 36 39.42	−1 13.62	1.0
E.	49 Herculis	−0.04	−0.03	− 2.71	+0.01	16 46 42.66	16 46 28.87	−1 13.79	1.0
E.	κ Ophiuchi	−0.05	−0.03	+ 0.06	+0.01	16 53 04.52	16 51 50.69	−1 13.83	1.0
E.	ε Herculis	−0.02	−0.03	+ 0.07	+0.01	16 56 49.22	16 55 35.46	−1 13.76	1.0
E.	d Herculis	−0.02	−0.03	−12.65	+0.01	16 58 18.15	16 57 04.24	−1 13.91	0.94
E.	60 Herculis	−0.05	−0.02	+ 0.06	+0.01	17 00 54.28	16 59 40.52	−1 13.76	1.0
E.	Gr. 2415	−0.00	−0.03	+ 0.08	+0.01	17 05 00.64	17 03 46.57	−1 14.07	1.0
E.	Carr. 770, L. C	−0.85	+0.36	− 0.39	+0.00	17 23 38.40	5 22 23.34	−1 15.06	0.042
W.	Carr. 770, L. C	−0.85	+0.06	+ 0.77	+0.00	17 23 37.05	5 22 23.34	−1 13.71	0.042
W.	51 Cephei, L. C	−1.46	+0.08	+ 1.34	−0.01	18 42 50.92	6 41 37.50	−1 13.42	0.003
E.	51 Cephei, L. C	−1.46	+1.10	− 0.68	−0.01	18 42 51.88	6 41 37.50	−1 14.38	0.003
E.	ζ Aquilæ	−0.05	+0.01	+ 0.06	−0.01	19 00 59.53	18 59 45.55	−1 13.98	1.0
E.	ι Lyræ	−0.01	+0.01	+ 0.07	−0.01	19 04 09.26	19 02 55.45	−1 13.81	1.0
E.	ω Aquilæ	−0.05	+0.01	+ 0.06	−0.02	19 13 16.63	19 12 02.76	−1 13.87	1.0
E.	δ Aquilæ	−0.06	+0.01	+ 0.06	−0.02	19 20 31.78	19 19 17.86	−1 13.92	1.0
E.	β Cygni	−0.03	+0.02	− 1.10	−0.02	19 26 59.97	19 25 46.12	−1 13.85	1.0
W.	κ Aquilæ	−0.07	−0.03	− 0.09	−0.02	19 31 30.27	19 30 16.47	−1 13.80	1.0
W.	γ Aquilæ	−0.05	−0.04	− 0.09	−0.02	19 41 38.61	19 40 24.88	−1 13.73	1.0
W.	α Aquilæ	−0.05	−0.04	− 0.09	−0.02	19 46 00.74	19 44 47.06	−1 13.68	1.0
W.	η Aquilæ	−0.06	−0.04	− 0.09	−0.02	19 47 26.29	19 46 12.51	−1 13.78	1.0
W.	β Aquilæ	−0.05	−0.04	− 0.09	−0.02	19 50 30.11	19 49 16.38	−1 13.73	1.0
W.	γ Sagittarii	−0.04	−0.04	− 0.10	−0.02	19 54 31.25	19 53 17.47	−1 13.78	1.0
W.	Carr. 3091	+0.62	−0.64	− 0.65	−0.01	20 18 34.84	20 17 19.58	−1 15.26	0.026
E.	Carr. 3091	+0.62	−0.71	+ 0.33	−0.03	20 18 34.06	20 17 19.58	−1 14.48	0.026

$\theta = -1^m\ 13^s.85$ at $17^h\ 37^m$ chronometer-time.

$\Delta t_0 = -1^m\ 13^s.811$ at $17^h\ 37^m$ chronometer-time.

Normal equations.

$$
\begin{aligned}
&+22.172\,\delta\theta + 10.970\,a + 0.640\,c - 10.650\,\rho + 0.210 = 0\\
&+10.970\,\delta\theta + 20.996\,a - 1.684\,c - 4.628\,\rho + 1.620 = 0\\
&+0.640\,\delta\theta - 1.684\,a + 51.970\,c + 2.255\,\rho - 2.741 = 0\\
&-10.650\,\delta\theta - 4.628\,a + 2.255\,c + 51.355\,\rho - 0.623 = 0
\end{aligned}
$$

$\delta\theta = +0^s.039$; $a = -0^s.092$; $c = +0^s.049$; $\rho = +0^s.010$, (gaining.)

Detroit, Michigan, July 18, 1876.—Observer, D. M. Lockwood.

Cl.	Stars.	A a	B b	C (Δi+a b r+c)	r ρ	t′	α	Δ t′	p
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
E.	Carr. 580, L. C	−0.55	−0.44	− 0.25	−0.03	16 01 00.06	3 59 37.81	−1 22.25	0.045
W.	Carr. 580, L. C	−0.55	−0.51	+ 0.53	−0.03	16 00 59.56	3 59 37.81	21.75	0.024
W.	ε Ophiuchi	−0.05	+0.07	− 0.09	−0.02	16 13 10.56	16 11 48.40	22.16	1.
W.	γ Herculis	−0.03	+0.09	− 0.09	−0.02	16 17 51.76	16 16 29.61	22.15	1.
W.	ω Herculis	−0.04	+0.09	− 0.09	−0.02	16 21 6.51	16 19 44.15	22.36	1.
W.	β Herculis	−0.03	+0.09	− 0.09	−0.02	16 26 18.17	16 24 56.02	22.15	1.
W.	ζ Ophiuchi	−0.06	+0.06	− 0.09	−0.02	16 31 44.94	16 30 22.82	22.12	1.
E.	ζ Herculis	−0.02	+0.08	+ 0.06	−0.02	16 38 1.45	16 36 39.39	22.06	1.
E.	η Herculis	−0.01	+0.09	+ 0.07	−0.02	16 40 3.59	16 38 41.36	22.23	1.
E.	κ Ophiuchi	−0.04	+0.03	+ 0.05	−0.01	16 56 57.52	16 55 35.44	22.08	1.
E.	d Herculis	−0.01	+0.04	+16.35	−0.01	16 58 26.62	16 57 04.21	22.41	0.91
E.	Gr. 2,415	−0.00	+0.03	+ 0.07	−0.01	17 05 09.03	17 03 46.54	22.49	1.
E.	Carr. 770, L. C	−0.72	−0.07	− 0.33	−0.00	17 23 46.89	5 22 23.98	22.91	0.042
W.	Carr. 770, L. C	−0.72	−0.16	+ 0.71	−0.00	17 23 46.43	5 22 23.98	22.45	0.042
W.	δ Ursæ Minoris	+0.91	+0.04	− 1.00	+0.01	18 13 51.07	18 12 28.61	22.46	0.013
E.	δ Ursæ Minoris	+0.91	−0.22	+ 0.47	+0.01	18 13 50.82	18 12 28.61	22.21	0.013
E.	α Lyræ	−0.01	+0.03	+ 0.07	+0.02	18 34 9.31	18 32 47.22	22.09	1.
E.	110 Herculis	−0.03	+0.03	+ 0.06	+0.02	18 41 44.64	18 40 22.52	22.12	1.
E.	β Lyræ	−0.01	+0.04	+ 0.06	+0.02	18 46 55.19	18 45 32.93	22.26	1.
E.	θ^1 Serpentis	−0.05	+0.03	+ 0.05	+0.02	18 51 28.63	18 50 06.32	22.31	1.
E.	ε Aquilæ	−0.04	+0.01	+ 0.05	+0.02	18 55 24.80	18 54 02.66	22.14	1.
W.	ζ Aquilæ	−0.14	+0.05	− 2.77	+0.02	19 01 7.97	18 59 45.56	22.41	1.
W.	ι Lyræ	−0.01	+0.05	− 0.10	+0.02	19 04 17.61	19 02 55.46	22.15	1.
W.	ω Aquilæ	−0.04	+0.04	− 0.09	+0.03	19 13 25.00	19 12 02.77	22.23	1.
W.	δ Aquilæ	−0.05	+0.03	− 0.09	+0.03	19 24 40.11	19 19 17.88	22.23	1.
W.	β Cygni	−0.02	+0.05	− 0.10	+0.03	19 27 8.26	19 25 46.14	22.12	1.
W.	κ Aquilæ	−0.06	+0.03	− 0.09	+0.03	19 31 38.73	19 30 16.50	22.23	1.
W.	λ Ursæ Minoris	+3.02	+0.23	− 3.20	+0.04	19 50 00.43	19 48 37.64	22.79	0.002
E.	λ Ursæ Minoris	+3.02	−1.69	+ 1.50	+0.04	19 50 1.10	19 48 37.64	23.46	0.002

$\theta = -1^m 22^s.20$ at $17^h 37^m$ chronometer time. $\Delta t_0 = -1^m 22^s.209$ at $17^h 37^m$ chronometer time.

Normal equations.

$$
\begin{aligned}
+21.093\,\delta\theta + 9.270\,a - 0.320\,c - 5.500\,\rho + 0.820 &= 0 \\
+9.270\,\delta\theta + 25.115\,a - 4.161\,c - 1.152\,\rho + 2.187 &= 0 \\
-0.320\,\delta\theta - 4.161\,a + 61.710\,c + 1.924\,\rho - 2.998 &= 0 \\
-5.500\,\delta\theta - 1.152\,a + 1.924\,c + 34.412\,\rho + 0.345 &= 0
\end{aligned}
$$

$\delta\theta = -0^s.009$; $a = -0^s.078$; $c = +0^s.043$; $\rho = -0^s.016$ (losing)

Mount Forest, Illinois, August 17, 1876.—Observer, Lieutenant Lockwood.

Cl.		Stars.	A a	B b	C (c+Δi+a b r)	r ρ	t'	α	Δt'	p
			s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	
E.	δ	Ursæ Minoris	−0.92	−0.07	− 0.45	+0.10	18 31 25.96	18 12 19.61	−19 06.25	0.013
W.	δ	Ursæ Minoris	−0.92	−1.11	− 0.07	+0.10	18 31 21.60	18 12 19.61	06.99	0.013
W.	1	Aquilæ	+0.06	−0.04	− 0.03	+0.09	18 47 37.30	18 28 30.70	06.60	1.0
W.	α	Lyræ	+0.01	−0.09	− 0.03	+0.09	18 51 53.41	18 32 46.93	06.51	1.0
W.	110	Herculis	+0.03	−0.08	− 0.03	+0.08	18 59 28.99	18 40 22.38	06.61	1.0
W.	β	Lyræ	+0.01	−0.10	− 0.03	+0.08	19 04 39.31	18 45 32.72	06.59	1.0
W.	θ'	Serpentis	+0.05	−0.07	− 0.03	+0.07	19 09 12.95	18 50 06.27	06.68	1.0
W.	ε	Aquilæ	+0.14	−0.08	− 0.03	+0.07	19 13 9.12	18 54 02.58	06.54	1.0
E.	ζ	Aquilæ	+0.04	−0.04	− 0.00	+0.07	19 18 52.17	18 59 45.50	06.67	1.0
E.	ι	Lyræ	+0.01	−0.05	0.00	+0.06	19 22 1.85	19 02 55.30	06.55	1.0
E.	ω	Aquilæ	+0.14	−0.04	0.00	+0.06	19 31 9.46	19 12 02.75	06.71	1.0
E.	δ	Aquilæ	+0.05	−0.04	0.00	+0.05	19 38 27.59	19 19 17.90	06.69	1.0
E.	β	Cygni	+0.02	−0.06	0.00	+0.05	19 44 52.70	19 25 46.08	06.62	1.0
E.	κ	Aquilæ	+0.06	−0.04	−13.76	+0.04	19 49 23.23	19 30 16.57	06.66	0.91
E.	λ	Ursæ Minoris	−3.04	−3.58	− 1.44	+0.03	20 07 26.63	19 48 21.00	05.63	0.001
W.	λ	Ursæ Minoris	−3.04	−5.25	− 0.24	+0.03	20 07 34.48	19 48 21.00	13.48	0.001
W.	ν	Cygni	+0.00	−0.22	− 0.03	−0.02	21 11 42.42	20 52 35.90	06.52	1.0
W.	61'	Cygni	+0.01	−0.19	− 0.03	−0.03	21 20 30.09	21 01 23.56	06.53	1.0
W.	ζ	Cygni	+0.02	−0.16	− 0.03	−0.03	21 26 49.12	21 07 42.54	06.58	1.0
W.	1	Draconis, L. C	+0.45	+0.10	+ 0.03	−0.04	21 38 22.21	9 19 15.68	06.53	0.026
E.	1	Draconis, L. C	+0.45	+0.44	+ 0.19	−0.04	21 38 22.66	9 19 15.68	06.98	0.026
E.	ξ	Aquarii	+0.06	−0.07	0.00	−0.05	21 50 19.28	21 31 12.58	06.70	1.0
E.	ι	Pegasi	+0.04	−0.09	0.00	−0.05	21 57 15.62	21 38 09.06	06.56	1.0
E.	20	Pegasi	+0.04	−0.09	− 6.87	−0.07	22 14 12.85	21 55 06.18	06.67	1.0
E.	α	Aquarii	+0.05	−0.07	− 6.74	−0.07	22 18 34.90	21 59 28.32	06.58	1.0
E.	θ	Aquarii	+0.06	−0.06	0.00	−0.08	22 29 27.65	22 10 20.96	06.69	1.0
W.	γ	Aquarii	+0.05	−0.11	− 0.03	−0.08	22 34 25.15	22 15 18.52	06.63	1.0
W.	π	Aquarii	+0.05	−0.11	− 0.03	−0.09	22 38 06.63	22 19 00.04	06.59	1.0
W.	η	Aquarii	+0.05	−0.11	− 0.03	−0.09	22 48 09.04	22 29 02.44	06.60	1.0
W.	ζ	Pegasi	+0.04	−0.12	− 0.03	−0.10	22 54 26.45	22 35 19.86	06.60	1.0
W.	λ	Pegasi	+0.03	−0.14	− 0.03	−0.10	22 59 43.18	22 40 36.66	06.52	1.0
W.	μ	Pegasi	+0.03	−0.14	− 0.03	−0.11	23 03 10.83	22 44 04.24	06.59	1.0
W.	λ	Aquarii	+0.06	−0.09	−13.74	−0.11	23 05 18.80	22 46 12.13	06.67	0.91
W.		3525 Carr	−0.47	−1.11	− 0.04	−0.11	23 14 31.89	22 55 24.50	07.59	0.017
E.		3525 Carr	−0.47	−0.87	− 0.24	−0.11	23 14 30.79	22 55 24.50	06.29	0.017

$\theta = -19^m\ 06^s.40$ at $20^h\ 45^m$ chronometer time. $\Delta t_0 = 19^m\ 06^s.669$ at $20^h\ 45^m$ chronometer time.

Normal equations.

$$+26.935\,\delta\theta + 12.480\,a - 6.080\,c - 6.070\,\rho + 4.890 = 0$$
$$+12.480\,\delta\theta + 17.520\,a - 0.977\,c - 6.229\,\rho + 1.540 = 0$$
$$-6.080\,\delta\theta - 0.977\,a + 49.928\,c + 6.151\,\rho - 0.922 = 0$$
$$-6.070\,\delta\theta - 6.229\,a + 6.151\,c + 69.516\,\rho - 3.894 = 0$$

$\delta\theta = -0^s.209,\ a = +0.077;\ c = -0^s.011;\ \rho = +0^s.046$, (gaining.)

Mount Forest, Illinois, August 23, 1876.—Observer, Lieutenant Lockwood.

Cl.		Stars.	A a	B b	C (c+abr+Δi)	r ρ	t'	α	Δ t'	p
			s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.
W.	δ	Ursæ Minoris	+ 8.59	+0.62	− 3.37	+0.02	18 31 23.57	18 12 17.50	−19 06.07	0.013
E.	δ	Ursæ Minoris	+ 8.59	+0.62	+ 2.85	+0.02	18 31 19.97	18 12 17.50	02.47	0.012
E.	1	Aquilæ	− 0.56	+0.05	+ 0.20	+0.02	18 47 33.36	18 28 30.65	02.71	1.0
E.	α	Lyræ	− 0.05	−0.10	+ 0.25	+0.02	18 51 49.34	18 32 46.83	02.51	1.0
E.	110	Herculis	− 0.28	−0.09	+ 0.21	+0.02	18 59 24.78	18 40 22.31	02.47	1.0
E.	β	Lyræ	− 0.13	−0.11	+ 0.23	+0.01	19 04 35.21	18 45 32.63	02.58	1.0
E.	θ¹	Serpentis	− 0.41	−0.08	+ 0.19	+0.01	19 09 08.82	18 50 06.21	02.61	1.0
E.		Aquilæ	− 0.34	−0.09	+ 0.20	+0.01	19 13 05.04	18 54 02.52	02.52	1.0
W.	λ	Aquilæ	− 0.37	−0.15	− 0.23	+0.01	19 18 47.94	18 59 45.44	02.50	1.0
W.	ι	Lyræ	− 0.19	−0.20	− 0.27	+0.01	19 21 57.52	19 02 55.21	02.31	1.0
W.	ω	Aquilæ	− 0.37	−0.14	− 0.23	+0.01	19 31 05.16	19 12 02.71	02.45	1.0
W.	δ	Aquilæ	− 0.45	−0.12	− 0.22	+0.01	19 38 20.37	19 19 17.85	02.52	1.0
W.	β	Cygni	− 0.19	−0.17	− 0.25	+0.01	19 44 48.47	19 25 46.02	02.45	1.0
W.	κ	Aquilæ	− 0.55	−0.10	− 0.23	+0.01	19 49 19.01	19 30 16.54	02.47	1.0
W.	λ	Ursæ Minoris	+28.44	−4.92	−10.73	+0.01	20 07 18.84	19 48 16.14	02.70	0.001
E.	λ	Ursæ Minoris	+28.44	−4.70	+ 9.65	+0.01	20 07 16.26	19 48 16.14	00.12	0.001
E.	1	Draconis, (L. C)	− 4.24	+0.36	− 1.19	−0.01	21 38 19.29	9 19 16.01	03.28	0.024
W.	1	Draconis, (L. C)	− 4.24	+0.52	+ 1.41	−0.01	21 38 19.13	9 19 16.01	03.12	0.027
W.	ξ	Aquarii	− 0.56	−0.10	− 0.23	−0.01	21 50 15.21	21 31 12.60	02.61	1.0
W.	ε	Pegasi	− 0.40	−0.12	− 0.23	−0.01	21 57 11.43	21 38 09.10	02.33	1.0
W.	μ	Capricorni	− 0.61	−0.09	− 0.23	−0.01	22 00 38.39	21 41 35.85	02.54	1.0
W.	20	Pegasi	− 0.36	−0.13	− 0.23	−0.01	22 14 08.72	21 55 06.22	02.50	1.0
W.	α	Aquarii	− 0.49	−0.11	− 0.22	−0.02	22 18 30.87	21 59 28.37	02.50	1.0
W.	θ	Pegasi	− 0.42	−0.12	− 0.23	−0.02	22 23 02.54	22 04 00.08	02.46	1.0
W.	θ	Aquarii	− 0.56	−0.09	+ 5.15	−0.02	22 29 23.51	22 10 21.01	02.50	1.0
E.	γ	Aquarii	− 0.50	−0.08	+ 0.19	−0.02	22 34 21.17	22 15 18.58	02.59	1.0
E.	π	Aquarii	− 0.48	−0.09	+ 0.19	−0.02	22 38 02.64	22 19 00.10	02.54	1.0
E.	η	Aquarii	− 0.49	−0.09	+12.60	−0.02	22 48 05.01	22 29 02.50	02.51	0.87
E.	ζ	Aquarii	− 0.38	−0.10	+ 5.68	−0.02	22 54 22.54	22 35 19.92	02.62	1.0
E.		Carr. 3525	+ 4.37	−1.13	+ 1.53	−0.02	23 14 26.06	22 55 24.73	01.33	1.016

$\theta = -19^m\ 02^s.30$ at $20^h\ 40^m$ chronometer time. $\Delta\ t_0 = -19^m\ 02^s.518$ at $20^h\ 40^m$ chronometer time.

Normal equations.

$$
\begin{aligned}
&\overset{s.}{+22.964}\ \delta\theta \overset{s.}{+12.280}\ a \overset{s.}{-\ 2.880}\ c \overset{s.}{-\ 2.140}\ \rho \overset{s.}{+14.400} = 0\\
&+12.280\ \delta\theta + 16.863\ a - 3.116\ c - 5.920\ \rho + 15.448 = 0\\
&-\ 2.880\ \delta\theta - 3.116\ a + 42.121\ c + 6.148\ \rho - 10.670 = 0\\
&-\ 2.140\ \delta\theta - 5.920\ a + 6.148\ c + 57.185\ \rho - 6.394 = 0
\end{aligned}
$$

$\delta\theta = -0^s.218$ $a = -0^s.720$ $c = +0^s.184$ $\rho = +0.^s009$, (gaining.)

Mount Forest, Illinois, August 25, 1876.—Observer, Lieutenant Lockwood.

Cl.	Stars.	A a	B b	C (Δi+a b r+c)	r ρ	t'	a	Δt'	p
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.
E.	λ Ursæ Minoris	−6.90	−1.06	+8.25	−0.11	20 07 17.61	19 48 14.52	19 03.09	0.002
W.	λ Ursæ Minoris	−6.90	−3.15	−9.93	−0.11	20 07 17.66	19 48 14.52	03.14	0.002
W.	θ Aquilæ	+0.12	−0.05	−0.21	−0.10	20 23 58.46	20 04 57.72	00.74	1.0
W.	24 Vulpeculæ	+0.06	−0.07	−0.23	−0.09	20 30 32.49	20 11 31.70	00.79	1.0
W.	γ Cygni	+0.01	−0.09	−0.27	−0.08	20 36 50.23	20 17 49.44	00.79	1.0
W.	π Capricorni	+0.16	−0.03	−0.22	−0.08	20 39 18.02	20 20 17.13	00.89	1.0
W.	ε Delphini	+0.09	−0.05	−0.21	−0.07	20 46 21.37	20 27 20.47	00.90	1.0
E.	α Delphini	+0.08	−0.06	+0.19	−0.07	20 52 56.62	20 33 55.85	00.77	1.0
E.	δ Delphini	+0.08	−0.06	+0.18	−0.06	20 56 44.10	20 37 43.32	00.78	1.0
E.	ε Aquarii	+0.14	−0.05	+0.18	−0.06	21 00 02.15	20 41 01.34	00.81	1.0
E.	ν Cygni	+0.00	−0.11	+0.23	−0.05	21 11 36.59	20 52 35.86	00.73	1.0
E.	61' Cygni	+0.01	−0.12	+0.22	−0.04	21 20 24.26	21 01 23.56	00.70	1.0
E.	1 Draconis, (L. C.)	+1.03	+0.25	−1.08	−0.02	21 38 17.77	9 19 16.16	01.61	0.029
W.	1 Draconis, (L. C.)	+1.03	+0.25	+1.30	−0.02	21 38 18.04	9 19 16.16	01.88	0.029
W.	Carr. 3525	+1.87	−0.58	−1.67	+0.07	23 14 26.78	22 55 24.78	02.00	0.01
E.	Carr. 3525	+1.87	−0.45	+1.39	+0.07	23 14 25.18	22 55 24.78	00.40	0.017
E.	τ Pegasi	−0.11	−0.05	+0.19	+0.09	23 33 34.06	23 14 33.26	00.80	1.0
E.	υ Pegasi	−0.11	−0.06	+0.19	+0.10	23 38 15.54	23 19 14.71	00.83	1.0
E.	θ Piscium	−0.18	−0.05	+0.18	+0.10	23 40 44.89	23 21 44.01	00.88	1.0
E.	72 Pegasi	−0.07	−0.08	+0.21	+0.11	23 46 52.13	23 27 51.24	00.89	1.0
E.	ι Andromedæ	+0.01	−0.11	+3.88	+0.11	23 51 07.53	23 32 06.60	00.93	1.0
E.	ι Piscium	−0.18	−0.07	+0.18	+0.11	23 52 38.61	23 33 37.77	00.84	1.0
W.	ω Piscium	−0.18	−0.11	−0.21	+0.13	0 12 00.78	23 52 59.98	00.80	1.0
W.	α Andromedæ	−0.08	−0.15	−0.74	+0.14	0 21 02.76	0 02 01.98	00.78	1.0
W.	γ Pegasi	−0.15	−0.13	−0.21	+0.15	0 25 55.04	0 06 54.32	00.72	1.0
W.	ι Ceti	−0.24	−0.10	−0.21	+0.15	0 32 10.79	0 13 10.00	00.79	1.0
W.	12 Ceti	−0.23	−0.11	−0.21	+0.16	0 42 46.59	0 23 45.97	00.62	1.0
W.	32 Camelop, (L. C.)	−2.32	+0.30	+1.72	+0.19	1 07 11.84	12 48 10.94	00.90	0.029
E.	32 Camelop, (L. C.)	−2.32	−0.30	−1.42	+0.19	1 07 12.44	12 48 10.94	01.50	0.029

$\theta = -19^m\ 00^s.5$ at 22^h chronometer time. $\theta t_0 = -19^m\ 00^s.805$ at 22^h chronometer time.

Normal equations.

$$
\begin{aligned}
&+21.154\,\delta\theta + 4.510\,a + 5.150\,a' + 1.700\,c - 11.120\,\rho + 6.290 = 0\\
&+4.510\,\delta\theta + 11.022\,a - 0.706\,c + 5.227\,\rho - 0.112 = 0\\
&+5.150\,\delta\theta + 7.342\,a' - 0.710\,c - 11.718\,\rho + 3.237 = 0\\
&+1.700\,\delta\theta - 0.706\,a - 0.710\,a' + 47.835\,c - 1.476\,\rho - 7.737 = 0\\
&-11.120\,\delta\theta + 5.227\,a - 11.718\,a' - 1.476\,c + 63.243\,\rho - 3.816 = 0
\end{aligned}
$$

$\delta\theta = -0^s.305$ $a = +0^s.175$ $a' = -0^s.308$ $c = +0^s.169$ $\rho = -0.061$, (losing.)

"a" azimuth *before* signals, "a'" azimuth after signals.

Mount Forest, Illinois, August 26, 1876.—Observer, Lieutenant Lockwood.

Cl.	Stars.	Aa	Bb	C(c+Δi+abr)	rρ	t'			α			Δt'		p
		s.	s.	s.	s.	h.	m.	s.	h.	m.	s.	m.	s.	s.
E.	λ Ursæ Minoris	−3.32	−0.66	+7.74	−0.04	20	07	20.21	19	48	13.63	−19	06.58	0.002
W.	λ Ursæ Minoris	−3.32	−0.57	−9.42	−0.04	20	07	12.16	19	48	13.63	−18	58.53	0.002
W.	θ Aquilæ	+0.06	−0.06	−0.20	−0.03	20	23	57.94	20	04	57.72	−19	00.22	1.0
W.	24 Vulpeculæ	+0.03	−0.08	−0.22	−0.03	20	30	31.90	20	11	31.70	−19	00.20	1.0
W.	γ Cygni	+0.00	−0.10	−0.26	−0.03	20	36	49.53	20	17	49.43	−19	00.10	1.0
W.	π Capricorni	+0.08	−0.04	−0.21	−0.02	20	39	17.48	20	20	17.12	−19	00.36	1.0
W.	ε Delphini	+0.04	−0.06	−0.20	−0.02	20	46	20.67	20	27	20.46	−19	00.21	1.0
E.	α Delphini	+0.04	−0.04	+0.18	−0.02	20	52	56.17	20	33	55.85	−19	00.32	1.0
E.	δ Delphini	+0.04	−0.05	+0.17	−0.02	20	56	44.60	20	37	43.32	−19	00.28	1.0
E.	ε Aquarii	+0.07	−0.03	+0.17	−0.02	21	00	01.73	20	41	01.34	−19	00.39	1.0
E.	ν Cygni	+0.00	−0.10	+0.22	−0.01	21	11	35.94	20	52	35.86	−19	00.08	1.0
E.	61' Cygni	+0.01	−0.11	+0.21	−0.01	21	20	23.77	21	01	23.55	−19	00.22	1.0
E.	ζ Cygni	+0.02	−0.11	+0.19	−0.01	21	26	42.79	21	07	42.53	−19	00.26	1.0
E.	1 Draconis, (L. C.)	+0.50	+0.18	−1.02	−0.01	21	38	17.20	9	19	16.23	−19	00.97	0.029
W.	1 Draconis, (L. C.)	+0.50	+0.33	−1.24	−0.01	21	38	16.75	9	19	16.23	−19	00.52	0.029
W.	Carr. 3525	−0.53	−0.95	−1.59	+0.03	23	14	26.01	22	55	24.80	−19	01.21	0.017
E.	Carr. 3525	−0.53	−0.89	+1.31	+0.03	23	14	24.66	22	55	24.80	−18	59.86	0.017
E.	υ Pegasi	+0.03	−0.12	+0.18	+0.03	23	38	14.91	23	19	14.72	−19	00.19	1.0
E.	θ Piscium	+0.05	−0.09	+0.17	+0.03	23	40	44.31	23	21	44.03	−19	00.28	1.0
E.	ι Andromedæ	+0.00	−0.16	+0.23	+0.04	23	51	06.80	23	32	06.62	−19	00.18	1.0
E.	ι Piscium	+0.05	−0.10	+0.17	+0.04	23	52	38.04	23	33	37.79	−19	00.25	1.0
W.	ψ Pegasi	+0.03	−0.12	−0.21	+0.04	0	05	14.30	23	46	14.09	−19	00.21	1.0
W.	ω' Piscium	+0.05	−0.10	+2.49	+0.05	0	12	00.45	23	52	59.99	−19	00.46	1.0
W.	γ Pegasi	+0.04	−0.09	−0.20	+0.05	0	25	54.55	0	06	54.34	−19	00.21	1.0
W.	ι Ceti	+0.07	−0.05	−0.20	+0.05	0	32	10.29	0	13	10.01	−19	00.28	1.0
W.	12 Ceti	+0.06	−0.05	−0.20	+0.05	0	42	46.23	0	23	45.98	−19	00.25	1.000
W.	32 Camelop., (L. C.)	+0.63	+0.57	+1.63	+0.06	1	07	10.37	12	48	10.82	−18	59.55	0.029
E.	32 Camelop., (L. C.)	+0.63	+0.33	−1.33	+0.06	1	07	11.66	12	48	10.82	−19	00.84	0.029

$\theta = -19^m\ 00^s.00$ at $21^h\ 55^m$ chronometer time. $\Delta t_0 = -19^m\ 00^s.255$ — at $21^h\ 55^m$ chronometer time.

Normal equations.

$$
\begin{array}{l}
+20.154\,\delta\theta + 9.480\,a + 0.670\,c - 8.640\,\rho + 4.060 = 0 \\
+9.480\,\delta\theta + 18.354\,a - 1.864\,c - 5.182\,\rho + 1.008 = 0 \\
+0.670\,\delta\theta - 1.864\,a + 46.430\,c + 2.395\,\rho - 7.030 = 0 \\
-8.640\,\delta\theta - 5.182\,a + 2.395\,c + 58.116\,\rho - 1.018 = 0
\end{array}
$$

$\delta\theta = -0^s.255$ $a = +0^s.084$ $c = +0^s.159$ $\rho = -0^s.019$, (losing.)

Saginaw, Michigan, September 12, 1876.—Observer, Lieutenant Lockwood.

Cl.	Stars.	Aa	Bb	$C(\Delta i+abr+c)$	t_0'	a	Δt	$r\rho$	$\Delta t'$
		s.	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*s.*	*m. s.*
W.	λ Ursæ Minoris	−7.92	−0.57	+ 9.00	19 51 16.93	19 47 55.48	−3 21.45	−0.14	−3 21.31
E.	λ Ursæ Minoris	−7.92	+1.62	−10.62	19 51 14.50	19 47 55.48	19.02	−0.14	18.88
E.	θ Aquilæ	+0.15	+0.02	− 0.17	20 08 16.65	20 04 57.57	19.08	−0.11	18.97
E.	24 Vulpeculæ	+0.08	+0.04	− 0.19	20 14 50.63	20 11 31.51	19.12	−0.11	19.01
E.	γ Cygni	+0.02	+0.06	− 0.22	20 21 08.35	20 17 49.18	19.17	−0.10	19.07
E.	π Capricorni	+0.20	+0.02	− 0.18	20 23 35.98	20 20 17.00	18.98	−0.09	18.89
E.	ε Delphini	+0.12	+0.05	− 0.18	20 30 39.41	20 27 20.34	19.07	−0.09	18.98
W.	α Delphini	+0.10	+0.01	+ 0.15	20 37 14.67	20 33 55.73	18.94	−0.08	18.86
W.	ε Aquarii	+0.17	+0.01	+ 0.14	20 44 20.11	20 41 01.26	18.85	−0.07	18.78
W.	ν Cygni	+0.01	+0.05	+ 0.19	20 55 54.74	20 52 35.68	19.06	−0.05	19.01
W.	61¹ Cygni	+0.03	+0.06	+ 0.18	21 04 42.34	21 01 23.42	18.92	−0.04	18.88
W.	ζ Cygni	+0.06	+0.07	− 7.68	21 11 01.27	21 07 42.43	18.84	−0.04	18.80
W.	1 Draconis, (L. C.)	+1.19	−0.26	− 1.18	21 22 36.88	9 19 17.76	19.12	−0.03	19.09
E.	1 Draconis, (L. C.)	+1.19	−0.45	+ 1.40	21 22 36.67	9 19 17.76	18.91	−0.03	18.88
E.	Carr. 3525	−1.21	+0.78	− 1.80	22 58 43.29	22 55 24.70	18.59	+0.09	18.68
W.	Carr. 3525	−1.21	+0.78	+ 1.51	22 58 43.10	22 55 24.70	18.40	+0.09	18.49
W.	τ Pegasi	+0.08	+0.13	+ 0.15	23 17 52.19	23 14 33.43	18.76	+0.12	18.88
W.	υ Pegasi	+0.08	+0.14	+ 0.15	23 22 33.71	23 19 14.89	18.82	+0.13	18.95
W.	θ Piscium	+0.13	+0.11	+ 0.14	23 25 02.92	23 21 44.19	18.73	+0.13	18.86
W.	72 Pegasi	+0.05	+0.16	+ 0.16	23 31 10.37	23 27 51.42	18.95	+0.14	19.09
W.	ι Andromedæ	+0.00	+0.20	+ 0.19	23 35 25.50	23 32 06.82	18.68	+0.14	18.82
W.	ι Piscium	+0.13	+0.12	+ 0.14	23 36 56.64	23 33 37.97	18.67	+0.14	18.81
E.	ψ Pegasi	+0.09	+0.16	− 0.18	23 49 33.11	23 46 14.29	18.82	+0.16	18.98
E.	ω Piscium	+0.13	+0.13	− 0.17	23 56 18.98	23 53 00.21	18.77	+0.17	18.94
E.	α Andromedæ	+0.06	+0.18	− 0.20	0 05 21.12	0 02 02.25	18.87	+0.18	19.05
E.	γ Pegasi	+0.10	+0.15	− 0.18	0 10 13.29	0 06 54.58	18.71	+0.19	18.90
E.	ι Ceti	+0.17	+0.09	− 0.17	0 16 28.99	0 13 10.27	18.72	+0.19	18.91
E.	12 Ceti	+0.16	+0.09	− 0.17	0 27 04.96	0 23 46.25	18.71	+0.20	18.91
E.	32 Camelop., (L. C.)	+2.00	−1.14	+ 1.91	0 51 28.06	12 48 09.16	18.90	+0.24	19.14
W.	32 Camelop., (L. C.)	+2.00	−0.85	− 1.62	0 51 28.03	12 48 09.16	18.87	+0.24	19.11

Chronometer fast at 21ʰ 40ᵐ — 3ᵐ 18ˢ.925, (excluding slow stars.) (Rate per hour losing 0ˢ.074.)

	Collimation.	Deviation.
	s.	*s.*
λ Ursæ Minoris,	+0.16, Cl. W.	0.240, E. of S.
1 Draconis,	+0.20, Cl. W.	0.173, E. of S.
Carr. 3525,	+0.19, Cl. W.	0.171, E. of S.
32 Camelop.,	+0.18, Cl. W.	0.238, E. of S.
Means......	+0.18, Cl. W.	0.206, E. of S.

Saginaw, Michigan, September 16, 1876.—Observer, Lieutenant Lockwood.

Cl.	Stars.	Aa	Bb	$C(\Delta i+abr+c)$	t'_o			α			Δt		rρ	Δt'	
		s.	s.	s.	h.	m.	s.	h.	m.	s.	m.	s.	s.	m.	s.
W.	λ Ursæ Minoris	−6.59	−3.66	+9.97	19	51	1.54	19	47	50.49	−3	11.05	−0.24	−3	10.81
E.	λ Ursæ Minoris	−6.59	−1.85	−11.59	19	50	53.17	19	47	50.49		02.68	−0.24		02.44
E.	θ Aquilæ	+0.11	−0.04	−2.85	20	08	09.88	20	04	57.53		12.35	−0.20		12.15
E.	24 Vulpeculæ	+0.06	−0.03	−0.21	20	14	43.63	20	11	31.45		12.18	−0.18		12.00
E.	γ Cygni	+0.01	−0.05	−0.25	20	21	01.28	20	17	49.12		12.16	−0.17		11.99
E.	π Capricorni	+0.16	−0.02	−0.20	20	23	29.29	20	20	16.96		12.33	−0.16		12.17
E.	ε Delphini	+0.09	−0.03	−0.19	20	30	32.60	20	27	20.30		12.30	−0.15		12.15
W.	α Delphini	+0.08	−0.05	+0.17	20	37	07.88	20	33	55.69		12.19	−0.13		12.06
W.	δ Delphini	+0.09	−0.05	+0.16	20	40	55.37	20	37	43.15		12.22	−0.13		12.09
W.	ε Aquarii	+0.14	−0.03	+0.16	20	44	13.46	20	41	01.23		12.23	−0.12		12.11
W.	ν Cygni	+0.01	−0.05	+0.21	20	55	47.82	20	52	35.62		12.20	−0.09		12.11
W.	61' Cygni	+0.02	−0.05	+0.20	21	04	35.36	21	01	23.37		11.99	−0.08		11.91
W.	ξ Cygni	+0.05	−0.04	+0.18	21	10	54.51	21	07	42.39		12.12	−0.06		12.06
W.	1 Draconis, (L. C.)	+0.97	+0.31	−1.31	21	22	30.67	9	19	18.21		12.46	−0.04		12.42
E.	1 Draconis, (L. C.)	+0.97	+0.21	+1.52	21	22	28.84	9	19	18.21		10.63	−0.04		10.59
E.	Carr. 3525	−2.24	−0.50	−1.95	22	58	36.18	22	55	24.56		11.62	+0.16		11.78
W.	Carr. 3525	−2.24	−1.02	+1.68	22	58	36.37	22	55	24.56		11.81	+0.16		11.97
W.	τ Pegasi	+0.16	−0.07	+0.17	23	17	45.22	23	14	33.45		11.77	+0.21		11.98
W.	υ Pegasi	+0.16	−0.06	+0.17	23	22	26.78	23	19	14.92		11.86	+0.22		12.08
W.	θ Piscium	+0.26	−0.04	+0.16	23	24	56.12	23	21	44.21		11.91	+0.22		12.13
W.	72 Pegasi	+0.11	−0.05	+0.19	23	31	03.36	23	27	51.45		11.91	+0.24		12.15
W.	ι Andromedæ	+0.01	−0.04	+0.22	23	35	18.71	23	32	06.84		11.87	+0.25		12.12
W.	ι Piscium	+0.26	−0.02	+0.16	23	36	49.86	23	33	38.00		11.86	+0.25		12.11
E.	ψ Pegasi	+0.19	−0.08	−0.20	23	49	26.14	23	46	14.32		11.82	+0.28		12.10
E.	ω Piscium	+0.26	−0.06	−0.19	23	56	11.96	23	52	00.25		11.71	+0.29		12.00
E.	α Andromedæ	+0.12	−0.07	−0.22	0	05	13.98	0	02	02.29		11.69	+0.31		12.00
E.	γ Pegasi	+0.21	−0.05	−0.20	0	10	06.41	0	06	54.62		11.79	+0.32		12.11
E.	ι Ceti	+0.34	−0.03	−0.19	0	16	21.98	0	13	10.31		11.67	+0.33		12.00
E.	32 Camelop. (L. C.)	+3.26	+0.04	+2.09	0	51	20.47	12	48	08.88		11.59	+0.40		11.99
W.	32 Camelop. (L. C.)	+3.26	+0.24	−1.79	0	51	19.74	12	48	08.88		10.86	+0.40		11.26

Chronometer fast at 21h 40m, chronometer time 3m 12s.072, (excluding slow stars.) Rate per chronometer hour losing 0s.128.

	Collimation.	Deviation.
	s.	s.
λ Ursæ Minoris,	+0.122, Cl. W.	0.031, E. of S.
1 Draconis,	+0.329, Cl. W.	0.305, E. of S.
Carr. 3525,	+0.189, Cl. W.	0.366, E. of S.
32 Camelop.	+0.162, Cl. W.	0.488, E. of S.
Mean	+0.200, Cl. W.	{ a = 0.168, E. of S. { a' = 0.427, E. of S.

"a" azimuth *before* signals, "a'" *after* signals.

Saint Louis, Michigan, October 11, 1876.—Observer, Lieutenant Lockwood.

Cl.	Stars.	Aa	Bb	$C(\Delta i+abr+c)$	t_o		Δt	rp	$\Delta t'$
		s.	s.	s.	h. m. s.	h. m. s.	m. s.		m. s.
W.	γ Aquarii	+ 3.64	−0.01	−0.41	22 20 31.97	22 15 18.53	−5 13.44	−0.13	−5 13.31
W.	π Aquarii	+ 3.48	0.00	−0.41	22 24 13.43	22 19 00.05	13.38	−0.13	13.25
W.	η Aquarii	+ 3.58	0.00	−0.41	22 34 15.86	22 29 02.50	13.36	−0.11	13.25
E.	ζ Pegasi	+ 2.87	−0.01	+0.39	22 40 33.43	22 35 19.94	13.49	−0.10	13.39
E.	λ Pegasi	+ 1.95	0.00	+0.41	22 45 50.16	22 40 36.72	13.44	−0.09	13.35
E.	μ Pegasi	+ 1.89	+0.01	−8.28	22 49 17.69	22 44 04.33	13.36	−0.09	13.27
E.	λ Aquarii	+ 4.04	+0.01	+0.38	22 51 25.82	22 46 12.29	13.53	−0.08	13.45
E.	Carr. 3525	−30.11	−0.46	+3.26	23 00 35.74	22 55 22.62	13.12	−0.07	13.05
E.	Carr. 3525	−30.11	−0.03	−3.33	23 00 36.39	22 55 22.62	13.77	−0.07	13.70
W.	τ Pegasi	+ 1.95	+0.12	−6.30	23 19 46.76	23 14 33.42	13.34	−0.04	13.30
W.	Carr. 76	−22.32	+0.25	−2.72	0 35 50.54	0 30 37.11	13.43	+0.08	13.51
E.	Carr. 76	−22.32	−0.25	+2.51	0 35 50.25	0 30 37.11	13.14	+0.08	13.22
E.	δ Piscium	+ 3.07	+0.06	+0.38	0 47 32.00	0 42 18.72	13.28	+0.10	13.38
E.	μ Andromedæ	+ 0.61	+0.10	+0.47	0 55 09.48	0 49 56.38	13.10	+0.11	13.21
E	ε Piscium	+ 3.07	+0.07	+0.38	1 01 47.50	0 56 34.30	13.20	+0.12	13.32
E.	β Andromedæ	+ 0.92	+0.10	+0.46	1 08 04.58	1 02 51.53	13.05	+0.13	13.18
E.	π Piscium	+ 1.43	+0.10	+0.44	1 10 07.12	1 04 54.00	13.12	+0.13	13.25
W.	υ Piscium	+ 1.64	+0.18	−0.46	1 17 56.31	1 12 43.09	13.22	+0.13	13.37
W.	θ Ceti	+ 4.10	+0.10	−0.41	1 23 06.62	1 17 53.39	13.23	+0.15	13.38
W.	η Piscium	+ 2.56	+0.15	−0.97	1 30 08.03	1 24 54.73	13.30	+0.16	13.46
W.	ν Piscium	+ 3.22	+0.13	+0.41	1 40 15.73	1 35 02.57	13.16	+0.18	13.34
W.	ο Piscium	+ 2.97	+0.14	−0.41	1 44 07.82	1 38 54.70	13.12	+0.19	13.31
W.	Carr. 299	−26.68	+0.71	−3.17	2 03 25.02	1 58 12.19	12.83	+0.21	13.04
E.	Carr. 299	−26.68	+0.42	+2.92	2 03 25.75	1 58 12.19	13.56	+0.21	13.77

Chronometer fast at $23^h\ 45^m$ chronometer time $5^m\ 13^s.321$, (excluding slow stars.)
Rate per chronometer hour losing $0^s.094$.

	Collimation.	Deviation.
	s.	s.
Carr. 3525,	+0.398, cl. W.	+5.105, E. of S.
Carr. 76,	+0.393, cl. E.	5.130, E. of S.
Carr. 299,	+0.328, cl. E.	5.131, E. of S.
Mean,	+0.373, cl. E.	5.122 E. of S.

Saint Louis, Michigan, October 12, 1876.—Observer, Lieutenant Lockwood.

Cl.	Stars.	Aa	Bb	C(Δi+abr+c)	t_0	α	Δt	rρ	Δt'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
E.	1 Draconis, (L. C.)	+9.24	−0.27	−2.72	21 24 33.73	9 19 21.77	−5 11.96	+0.03	−5 11.99
W.	1 Draconis, (L. C.)	+9.24	−0.84	+2.93	21 24 33.64	9 19 21.77	11.87	+0.03	11.90
W.	ζ Aquarii	+1.29	+0.16	−0.44	21 36 24.06	21 31 12.35	11.71	+0.02	11.73
W.	ε Pegasi	+0.92	+0.24	−0.44	21 41 20.47	21 38 08.83	11.64	+0.02	11.66
W.	μ Capricorni	+1.40	+0.17	−0.45	21 51 47.26	21 46 35.66	11.60	+0.02	11.62
W.	20 Pegasi	+0.85	+0.28	−0.45	22 00 17.53	21 55 06.04	11.49	+0.02	11.51
W.	α Aquarii	+1.13	+0.23	−0.44	22 04 39.74	21 59 27.22	11.52	+0.02	11.54
W.	ϑ Pegasi	+1.00	+0.26	−0.44	22 09 11.53	22 03 59.95	11.58	+0.02	11.60
W.	θ Aquarii	+1.29	+0.21	−0.44	22 15 32.40	22 10 20.92	11.48	+0.02	11.50
E.	γ Aquarii	+1.14	+0.16	+0.41	22 20 30.10	22 15 18.52	11.58	+0.02	11.60
E.	η Aquarii	+1.13	+0.16	+0.41	22 34 14.15	22 29 02.49	11.66	+0.01	11.67
E.	ζ Pegasi	+0.90	+0.20	+0.42	22 40 31.64	22 35 19.92	11.72	+0.01	11.73
E.	λ Pegasi	+0.61	+0.25	+0.45	22 45 48.84	22 40 36.71	11.63	+0.01	11.64
E.	μ Pegasi	+0.60	+0.26	+0.45	22 49 15.93	22 44 04.32	11.61	+0.01	11.62
E.	λ Aquarii	+1.27	+0.17	+0.41	22 51 23.96	22 16 12.28	11.68	+0.01	11.69
E.	Carr. 3525	−9.44	+1.26	+3.50	23 00 35.04	22 55 22.50	12.54	+0.01	12.55
W.	Carr. 3525	−9.44	+1.56	−3.78	23 00 33.77	22 55 22.50	11.27	+0.01	11.28
W.	Carr. 76	−7.00	+1.67	−2.91	0 35 48.75	0 30 37.08	11.67	−0.01	11.66
E.	Carr. 76	−7.00	+1.25	+2.70	0 35 48.32	0 30 37.08	11.24	−0.01	11.23
E.	δ Piscium	+0.97	+0.25	+0.41	0 47 29.50	0 42 18.73	11.77	−0.02	11.75
E.	μ Andromedæ	+0.19	+0.38	+0.51	0 55 07.96	0 49 56.38	11.58	−0.02	11.56
E.	ε Piscium	+0.97	+0.25	+0.41	1 01 46.04	0 56 34.31	11.73	−0.02	11.71
E.	β Andromedæ	+0.29	+0.38	+0.50	1 08 03.26	1 02 51.54	11.72	−0.02	11.70
E.	τ Piscium	+0.45	+0.35	+0.47	1 10 05.64	1 04 54.01	11.63	−0.02	11.61
W.	Ceti	+1.29	+0.26	−0.44	1 23 04.99	1 17 53.40	11.59	−0.02	11.57
W.	η Piscium	+0.80	+0.39	−0.45	1 30 06.48	1 24 54.74	11.74	−0.03	11.71
W.	ν Piscium	+1.01	+0.35	−0.44	1 40 14.12	1 35 02.58	11.54	−0.03	11.51
W.	ο Piscium	+0.93	+0.37	−0.44	1 44 06.24	1 38 54.71	11.53	−0.03	11.50
W.	Carr. 299	−8.37	+2.30	−3.39	2 03 24.58	1 58 12.96	12.32	−0.03	12.29
E.	Carr. 299	−8.37	+1.84	+3.15	2 03 23.96	1 58 12.26	11.70	−0.03	11.67

Chronometer fast at $23^h 30^m$, chronometer time $5^m 11^s.624$, (excluding slow stars.) Rate per hour gaining $0^s.013$.

	Collimation.	Deviation.
	b.	s.
1 Draconis, (L. C.,)	+0.406	+1.548
Carr. 3525,	+0.332	+1.639
Carr. 76,	+0.430	+1.547
Carr. 299,	+0.438	+1.690
Means,	+0.401, Cl. E.	+1.606, (E. of S.)

Detroit, Michigan, October 23, 1876.—Observer, D. W. Lockwood.

Cl.	Stars.	Aa	Bb	$C(\Delta t+abr+c)$	$r\rho$	t'	α	$\Delta t'$	p
		s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*s.*
E.	1 Draconis, (L. C.)	+40.68	+0.11	−0.34	+0.08	21 18 41.88	9 19 23.58	+0 41.70	0.029
W.	1 Draconis, (L. C.)	+40.68	+0.11	+0.56	+0.08	21 18 40.73	9 19 23.58	42.85	0.029
W.	ε Pegasi	+ 3.82	−0.05	−0.11	+0.07	21 37 26.27	21 38 08.69	42.42	1.0
W.	μ Capricorni	+ 5.98	0.00	−0.11	+0.06	21 45 53.26	21 46 35.53	42.27	1.0
W.	20 Pegasi	+ 3.55	+0.02	−0.11	+0.06	21 54 23.64	21 55 05.91	42.27	1.0
W.	α Aquarii	+ 4.73	+0.02	−0.01	+0.05	21 58 45.83	21 59 28.10	42.27	1.0
W.	θ Pegasi	+ 4.17	+0.03	−0.11	+0.05	22 03 17.55	22 03 59.82	42.27	1.0
W.	θ Aquarii	+ 5.42	+0.03	−0.11	+0.05	22 09 38.51	22 10 20.81	42.30	1.0
E.	γ Aquarii	+ 4.87	+0.01	+0.07	+0.04	22 14 36.14	22 15 18.40	42.26	1.0
E.	π Aquarii	+ 4.59	+0.02	+0.07	+0.04	22 18 17.63	22 18 59.93	42.30	1.0
E.	η Aquarii	+ 4.73	+0.07	+0.07	+0.03	22 28 20.20	22 29 02.40	42.20	1.0
E.	ζ Pegasi	+ 3.75	+0.08	+0.07	+0.03	22 34 37.60	22 35 19.83	42.23	1.0
E.	λ Pegasi	+ 2.50	+0.09	+0.08	+0.02	22 39 54.35	22 40 36.60	42.25	1.0
E.	μ Pegasi	+ 2.36	+0.09	+0.08	+0.02	22 43 21.89	22 44 04.21	42.32	1.0
E.	λ Aquarii	+ 5.42	+0.05	+0.07	+0.02	22 45 29.98	22 46 12.19	42.21	1.0
E.	Carr. 3525	−41.79	+0.27	+0.44	+0.01	22 55 38.02	22 55 21.12	43.10	0.017
W.	Carr. 3525	−41.79	−0.08	−0.72	+0.01	22 55 38.73	22 55 21.12	42.39	0.017
W.	4 Pegasi	+ 2.99	+0.04	−0.11	−0.02	23 45 32.14	23 46 14.37	42.23	1.0
W.	ω Piscium	+ 4.10	+0.03	−0.11	−0.03	23 52 17.95	23 53 00.31	42.36	1.0
W.	α Andromedæ	+ 1.95	+0.05	−0.12	−0.04	0 01 20.13	0 02 02.38	42.25	1.0
W.	γ Pegasi	+ 3.34	+0.05	−0.11	−0.04	0 06 12.47	0 06 54.74	42.27	1.0
W.	ι Ceti	+ 5.56	+0.04	−0.11	−0.04	0 12 28.23	0 13 10.45	42.22	1.0
W.	Carr. 76	−31.08	−0.04	−0.56	−0.06	0 30 54.53	0 30 36.76	42.23	0.030
E.	Carr. 76	−31.08	+0.08	+0.34	−0.06	0 30 54.33	0 30 36.76	42.43	0.031
E.	δ Piscium	+ 4.03	+0.10	+0.07	−0.07	0 41 36.52	0 42 18.74	42.22	1.0
E.	μ Andromedæ	+ 0.70	+0.15	+0.09	−0.07	0 49 14.14	0 49 56.41	42.27	1.0
E.	ε Piscium	+ 4.03	+0.09	+0.07	−0.08	0 55 52.00	0 56 34.36	42.36	1.0
E.	ι Piscium	+ 2.09	+0.10	+0.08	−0.09	1 12 00.84	1 12 43.16	42.32	1.0
E.	θ Ceti	+ 5.49	+0.05	+0.07	−0.09	1 17 11.16	1 17 53.46	42.30	1.0
E.	η Piscium	+ 3.34	+0.08	+0.08	−0.10	1 24 12.61	1 24 54.82	42.21	1.0
W.	υ Piscium	+ 4.24	+0.03	−0.10	−0.10	1 34 20.35	1 35 02.67	42.32	1.0
W.	ο Piscium	+ 3.89	+0.07	−0.11	−0.11	1 38 12.50	1 38 54.81	42.31	1.0
W.	Carr. 299	−37.06	−0.25	−0.65	−0.12	1 57 31.12	1 58 12.78	41.66	0.018
E.	Carr. 299	−37.06	+0.44	+0.39	−0.12	1 57 30.90	1 58 12.78	41.88	0.018

$\theta = +42^s.00$, at $23^h\ 12^m$ chronometer-time.

$\Delta t_o = +42.^s279$ at $23^h\ 12^m$, chronometer-time.

Normal equations.

$$
\begin{aligned}
+26.189\,\delta\theta + 14.290\,a + 0.330\,c - 7.630\,\rho - 106.340 &= 0\\
+14.290\,\delta\theta + 14.512\,a - 0.846\,c - 0.932\,\rho - 104.788 &= 0\\
+0.330\,\delta\theta - 0.846\,a + 39.217\,c - 6.018\,\rho + 3.500 &= 0\\
-7.630\,\delta\theta - 0.932\,a - 6.018\,c + 49.854\,\rho + 6.795 &= 0
\end{aligned}
$$

$= +0.279;\ a = +6.^s953;\ c = +0.^s064;\ \rho = +0.^s044$, (gaining.)

Cairo, Illinois, December 5, 1876.—Observer, Lieutenant Lockwood.

Cl.		Stars.	Aa	Bb	c (Δi+abr+c.)	t_0'	α	Δt	rρ	Δt'
			s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
E.	α	Ursæ Minoris	−8.81	+1.33	+5.43	1 38 37.71	1 13 51.04	−24 46.67	−0.13	−24 46.54
W.	α	Ursæ Minoris	−8.81	+0.45	−6.88	1 38 34.10	1 13 51.04	43.06	−0.13	42.93
W.	β	Arietis	+0.08	+0.02	−0.20	2 12 38.33	1 47 51.62	46.71	−0.10	46.61
W.	γ	Andromedæ	+0.03	+0.01	−9.37	2 21 08.78	1 56 22.02	46.76	−0.09	46.67
W.	α	Arietis	+0.07	0.00	−0.20	2 25 02.08	2 00 15.36	46.72	−0.09	46.63
W.	ξ^1	Ceti	+0.13	−0.01	−0.19	2 31 16.55	2 06 29.78	46.77	−0.08	46.69
W.	γ	Triangula	+0.02	−0.02	−0.22	2 34 47.85	2 10 01.26	46.59	−0.08	46.51
W.	o	Ceti	+0.17	−0.01	−0.19	2 37 55.78	2 13 09.02	46.76	−0.08	46.68
E.	ξ^2	Ceti	+0.13	+0.01	+0.15	2 46 24.96	2 21 38.18	46.78	−0.07	46.71
E.	ν	Arietis	+0.08	+0.01	+0.16	2 56 37.75	2 31 51.08	46.67	−0.07	46.60
E.	γ	Ceti	+0.15	+0.01	+0.15	3 01 43.47	2 36 56.78	46.69	−0.06	46.63
E.	41	Arietis	+0.05	+0.01	+0.17	3 07 32.48	2 42 45.78	46.70	−0.06	46.64
E.	η	Eridani	+0.19	+0.01	+0.15	3 15 13.06	2 50 26.35	46.71	−0.05	46.67
E.	α	Ceti	+0.14	+0.01	+0.15	3 20 38.87	2 55 52.18	46.69	−0.05	46.64
E.		Carr. 491	−3.05	+0.09	+1.94	3 51 24.94	3 26 37.10	47.84	−0.03	47.81
W.		Carr. 491	−3.05	+0.31	−2.46	3 51 25.43	3 26 37.10	48.33	−0.03	48.30
W.	ε	Ursæ Minoris, L. C	+1.68	+0.20	+1.19	4 23 16.00	16 58 29.17	46.83	+0.04	46.87
E.	ε	Ursæ Minoris, L. C	+1.68	+0.05	−0.93	4 23 15.94	16 58 29.17	46.77	+0.04	46.81
E.	β	Orionis	+0.19	0.00	+0.15	5 33 25.62	5 08 39.01	46.61	+0.05	46.66
E.	τ	Orionis	+0.18	0.00	+0.15	5 36 26.05	5 11 39.50	46.55	+0.05	46.60
E.	β	Tauri	+0.05	−0.01	+0.17	5 43 19.08	5 18 32.53	46.55	+0.05	46.60
E.	δ	Orionis	+0.16	−0.01	+0.15	5 50 31.37	5 25 44.77	46.60	+0.06	46.66
E.	ϕ^1	Orionis	+0.12	−0.01	+0.15	5 52 51.98	5 28 05.43	46.55	+0.06	46.61
E.		Orionis	+0.16	−0.01	+0.15	5 54 46.27	5 29 59.71	46.56	+0.06	46.62
W.	130	Tauri	+0.09	+0.01	−0.20	6 05 3.88	5 40 17.26	46.62	+0.07	46.69
W.	α	Orionis	+0.13	−0.01	−0.19	6 13 18.67	5 48 32.14	46.56	+0.07	46.63
W.	θ	Aurigæ	0.00	−0.03	−0.23	6 16 8.25	5 51 21.70	46.55	+0.08	46.63
W.	66	Orionis	+0.14	−0.03	−0.19	6 23 16.32	5 58 29.75	46.57	+0.08	46.65
W.	δ	Ursæ Minoris, L. C	+3.70	+0.17	+2.72	6 36 24.31	18 11 37.95	46.36	+0.09	46.45
E.	δ	Ursæ Minoris, L. C	+3.70	+0.03	−2.14	6 36 24.29	18 11 37.95	46.34	+0.09	46.43

Chronometer fast at 4^h 30^m, chronometer time 24^m $46^s.638$, (excluding slow stars.) Rate per chronometer hour $0^s.044$, losing.

Collimation.		Deviation.
	s.	s.
α Ursæ Minoris,	+0.144, Cl. E.	+0.209, E. of S.
Carr. 491.	+0.140, Cl. E.	+0.351, E. of S.
ε Ursæ Minoris,	+0.146, Cl. E.	+0.214, E. of S.
δ Ursæ Minoris,	+0.146, Cl. E.	+0.278, E. of S.
Means.......	+0.144, Cl. E.	+0.263, E. of S.

Cairo, Illinois, December 19, 1876.—Observer, Lieutenant Lockwood.

Cl.	Stars.	Aa	Bb	C(Δi+abr+c.)	t_0'	α	t	rp	t'
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
E.	α Ursæ Minoris	−2.92	+0.90	+4.28	1 38 12.23	1 13 40.71	−24 31.52	−0.13	−24 31.39
W.	α Ursæ Minoris	−2.92	−1.06	−5.99	1 38 10.21	1 13 40.71	29.51	−0.13	29.38
W.	β Arietis	+0.03	−0.02	−0.17	2 12 25.29	1 47 51.54	33.75	−0.10	33.65
W.	γ Andromedæ	−0.01	−0.02	−0.22	2 20 55.71	1 56 21.91	33.80	−0.09	33.71
W.	α Arietis	+0.02	−0.02	−0.17	2 24 48.96	2 00 15.29	33.67	−0.09	33.58
W.	ξ^1 Ceti	+0.04	−0.02	−0.16	2 31 03.49	2 06 29.71	33.78	−0.08	33.70
W.	γ Trianguli	+0.01	−0.03	−0.19	2 34 34.91	2 10 01.18	33.73	−0.08	33.65
W.	o Ceti	+0.06	−0.02	−0.16	2 37 42.68	2 13 08.95	33.73	−0.08	33.65
E.	ξ^2 Ceti	+0.04	0.00	+0.13	2 46 11.98	2 21 38.13	33.85	−0.07	33.78
E.	ν Arietis	+0.03	+0.01	+0.13	2 56 24.82	2 31 51.03	33.79	−0.07	33.72
E.	γ Ceti	+0.05	+0.01	+1.18	3 01 30.61	2 36 56.75	33.86	−0.06	33.80
E.	41 Arietis	+0.02	+0.02	+0.14	3 07 19.63	2 42 45.76	33.87	−0.06	33.81
E.	η Eridani	+0.06	+0.02	+0.13	3 14 00.13	2 50 26.32	33.81	−0.05	33.76
E.	α Ceti	+0.05	+0.03	+0.13	3 20 25.94	2 55 52.16	33.78	−0.05	33.73
E.	Carr. 491	−1.01	+0.40	+1.53	3 51 10.33	3 26 35.90	34.43	−0.03	34.40
W.	Carr. 491	−1.01	+0.21	−2.15	3 51 10.41	3 26 35.90	34.51	−0.03	34.48
W.	ε Ursæ Minoris, L. C	+0.56	+0.39	+0.97	5 23 01.92	16 58 29.08	32.84	+0.04	32.92
E.	ε Ursæ Minoris, L. C	+0.56	+0.21	−0.74	5 23 02.80	16 58 29.08	33.72	+0.04	33.76
E.	β Orionis	+0.06	+0.03	+0.13	5 33 12.90	5 08 39.16	33.74	+0.05	33.79
E.	τ Orionis	+0.06	+0.02	+0.13	5 36 13.24	5 11 39.65	34.59	+0.05	33.64
E.	β Tauri	+0.02	+0.01	+0.14	5 43 06.55	5 18 32.72	33.83	+0.05	33.88
E.	δ Orionis	+0.05	−0.01	+0.13	5 50 18.57	5 25 44.95	33.62	+0.06	33.68
E.	φ Orionis	+0.04	−0.02	+0.13	5 52 39.25	5 28 05.63	33.62	+0.06	34.68
E.	ε Orionis	+0.65	−0.02	+0.13	5 54 33.43	5 29 59.88	33.55	+0.06	33.61
W.	υ Aurigæ	+0.00	−0.05	−0.21	6 07 33.58	5 42 59.82	33.76	+0.07	33.83
W.	α Orionis	+0.04	−0.04	−0.16	6 13 05.87	5 48 32.35	33.52	+0.07	33.59
W.	θ Orionis	+0.00	−0.06	−0.20	6 15 55.61	5 51 21.96	33.65	+0.08	33.73
W.	66 Orionis	+0.05	−0.04	−0.16	6 23 03.58	5 58 29.98	33.60	+0.08	33.68
W.	δ Ursæ Minoris, L. C	+1.22	+0.65	+2.37	6 36 09.30	18 11 35.82	33.48	+0.09	33.57
E.	δ Ursæ Minoris, L. C	+1.22	+0.56	−1.69	6 36 09.05	18 11 35.82	33.23	+0.09	33.32

Chronometer fast at $4^h\ 30^m$, chronometer time $24^m\ 33^s.711$, (excluding slow stars.) Rate per chronometer hour losing $0^s.043$.

	Collimation.	Deviation.
	s.	s.
α Ursæ Minoris,	+ 0.096, Cl. E.	− 0.006, W. of E.
Carr. 491,	+ 0.122, Cl. E.	+ 0.145, E. of S.
ε Ursæ Minoris,	+ 0.140, Cl. E.	+ 0.099, E. of S.
δ Ursæ Minoris,	+ 0.113, Cl. E.	+ 0.110, E. of S.
Means	+ 0.118, Cl. E.	+ 0.087, E. of S.

Detroit, Michigan, March 10, 1877.—Observer, Lieutenant Lockwood.

Cl.	Stars.	A′a	Bb	C(Δt+abr+ċ)	t_0'	a	Δt	rρ	Δt′
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
W.	δ Ursæ Minoris, L. C	− 8.79	+0.09	+1.85	6 17 24.79	18 11 48.91	−5 35.88	−0.43	−5 35.45
E.	δ Ursæ Minoris, L. C	− 8.79	+1.69	−1.18	6 17 25.21	18 11 48.91	36.30	−0.43	35.87
E.	γ Germinorum	− 0.30	−0.06	+0.11	6 36 13.96	6 30 37.92	36.04	−0.36	35.68
E.	15 Monocerotis	− 0.36	−0.06	+0.11	6 39 49.73	6 34 13.75	35.98	−0.35	35.63
E.	ε Germinorum	− 0.22	−0.07	+0.11	6 41 59.54	6 36 23.51	36.03	−0.35	35.68
E.	ζ Germinorum	− 0.34	−0.06	+0.11	6 44 00.64	6 38 24.65	35.99	−0.34	35.65
E.	18 Monocerotis	− 0.43	−0.05	+0.10	6 47 04.33	6 41 28.29	36.04	−0.34	35.70
E.	θ Germinorum	− 0.12	−0.08	+0.12	6 50 18.70	6 44 42.69	36.01	−0.33	35.68
W.	ξ Germinorum	− 0.26	−0.11	−0.14	7 02 26.38	6 56 50.52	35.86	−0.28	35.58
W.	63 Aurigæ	− 0.04	−0.14	−0.17	7 08 49.56	7 03 13.74	35.82	−0.26	35.56
W.	λ Germinorum	− 0.30	−0.10	−0.14	7 16 38.97	7 11 03.18	35.79	−0.23	35.56
W.	δ Germinorum	− 0.25	−0.10	−0.14	7 18 24.17	7 12 48.47	35.70	−0.23	35.47
W.	ι Germinorum	− 0.19	−0.11	−0.15	7 23 42.91	7 18 07.18	35.73	−0.21	35.52
W.	β Canis Minoris	− 0.38	−0.08	−0.13	7 26 06.28	7 20 30.50	35.78	−0.21	35.57
W.	λ Ursæ Minoris, L. C	−26.97	+5.19	+5.89	7 51 37.26	19 45 01.34	35.92	−0.12	35.80
E.	λ Ursæ Minoris, L. C	−26.97	+7.24	−3.75	7 51 37.26	19 45 01.34	35.92	−0.12	35.80
W.	κ Cancri	− 4.34	+0.06	−0.32	9 06 42.61	9 01 07.18	35.43	+0.12	35.55
W.	ο Hydræ	− 5.24	+0.06	−0.31	9 13 35.34	9 07 59.91	35.43	+0.14	35.57
W.	38 Lyncis	− 0.90	+0.11	−0.39	9 16 49.36	9 11 13.89	35.47	+0.14	35.61
W.	40 Lyncis	− 1.31	+0.11	−0.38	9 19 11.59	9 13 36.16	35.43	+0.16	35.59
W.	α Hydræ	− 6.39	+0.07	−0.32	9 27 10.06	9 21 34.57	35.49	+0.18	35.67
W.	10 Leonis Minoris	− 0.98	+0.14	−0.39	9 32 19.25	9 26 44.05	35.20	+0.20	35.40
E.	ο Leonis	− 4.42	+0.09	+0.29	9 40 12.71	9 34 37.29	35.42	+0.22	35.64
E.	ε Leonis	− 2.78	+0.12	+0.31	9 44 29.95	9 38 54.61	35.34	+0.24	35.58
E.	μ Leonis	− 2.46	+0.13	+0.32	9 51 23.95	9 45 48.45	35.50	+0.26	35.76
E.	19 Leonis Minoris	− 0.16	+0.18	+0.38	9 55 47.11	9 50 11.86	35.25	+0.27	35.52
E.	π Leonis	− 4.58	+0.12	+0.29	9 59 20.37	9 53 44.98	35.39	+0.29	35.68
E.	η Leonis	− 3.60	+0.14	+0.30	10 06 15.29	10 00 39.87	35.42	+0.31	35.73
E.	30 Camelopardalis	+45.12	+0.35	+2.16	10 21 47.31	10 16 11.90	35.41	+0.35	35.76
W.	30 Camelopardalis	+45.12	+0.13	−2.44	10 21 47.29	10 16 11.90	35.39	+0.35	35.74

Chronometer fast at 8^h 30^m, chronometer time 5^m $35^s.608$, (excluding slow stars.) Rate per chronometer hour losing $0^s.192$.

	Collimation.	*Deviation.*
Before signals:		
δ Ursæ Minoris	+ $0^s.101$, Cl. E.	− $0^s.673$, W. of S.
λ Ursæ Minoris	+ $0^s.085$, Cl. E.	− $0^s.675$, W. of S.
After signals:		
30 Camelop.	+ $0^s.273$, Cl. E.	− $0^s.187$, W. of S.

NOTE.—The transit was moved in azimuth just after signals by the telescope slipping into the wyse. D. W. L.

Detroit, Michigan, March 19, 1877.—Observer, Lieutenant Lockwood.

Cl.	Stars.	Aa	Bb	C(Δi ⊤ abr+c)	t′₀	a	Δt	rρ	Δt
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s	m. s.
W.	δ Ursæ Minoris, L. C	−2.45	+0.12	+ 5.40	6 17 2.39	18 11 52.23	−5 10.16	−0.35	−5 09.81
E.	δ Ursæ Minoris, L. C	−2.45	+0.55	− 4.89	6 17 2.00	18 11 52.23	09.77	−0.35	09.42
E.	γ Germinorum	−0.08	−0.02	+ 0.33	6 35 47.35	6 30 37.77	09.56	−0.29	09.29
E.	15 Monocerotis	−0.10	−0.02	+ 0.32	6 39 23.12	6 34 13.60	09.52	−0.29	09.23
E.	ε Germinorum	−0.06	−0.02	+ 0.35	6 41 33.00	6 36 23.35	09.65	−0.28	09.37
E.	ξ Germinorum	−0.09	−0.01	+ 0.32	6 43 34.13	6 38 24.50	09.63	−0.28	09.35
E.	18 Monocerotis	−0.12	−0.01	+ 0.32	6 46 37.73	6 41 28.14	09.59	−0.27	09.32
E.	θ Germinorum	−0.03	−0.01	+ 0.38	6 49 52.24	6 44 42.51	09.73	−0.26	09.47
W.	ζ Germinorum	−0.07	+0.03	− 0.37	7 02 59.80	6 56 50.37	09.43	−0.23	09.20
W.	63 Aurigæ	−0.01	+0.04	− 0.45	7 08 23.23	7 03 13.55	09.68	−0.21	09.47
W.	λ Germinorum	−0.08	+0.03	− 0.36	7 16 12.56	7 11 03.04	09.52	−0.19	09.33
W.	δ Germinorum	−0.07	+0.04	− 0.37	7 17 57.72	7 12 48.33	09.39	−0.19	09.20
W.	ι Germinorum	−0.05	+0.04	− 0.39	7 23 16.46	7 18 07.03	09.43	−0.17	09.26
W.	β Canis Minoris	−0.10	+0.03	− 0.35	7 25 39.80	7 20 30.37	09.43	−0.17	09.26
W.	λ Ursæ Minoris, L. C	−7.63	+0.32	+17.14	7 51 20.10	19 46 10.40	09.70	−0.10	09.60
E.	λ Ursæ Minoris, L. C	−7.63	+1.62	−15.53	7 51 20.61	19 46 10.40	10.21	−0.10	10.11
E.	76 Draconis, L. C	−1.18	+0.52	− 2.10	8 56 21.33	20 51 12.19	09.14	+0.07	09.21
W.	76 Draconis, L. C	−1.18	+0.41	+ 2.32	8 56 21.06	20 51 12.19	08.87	+0.07	08.94
W.	κ Cancri	−0.10	−0.09	− 0.35	9 06 16.29	9 01 07.11	09.18	+0.09	09.27
W.	θ Hydræ	−0.12	−0.07	− 0.35	9 13 68.91	9 07 59.85	09.06	+0.11	09.17
W.	38 Lyncis	−0.02	−0.11	− 0.43	9 16 23.00	9 11 13.80	09.20	+0.12	09.32
W.	40 Lyncis	−0.03	−0.10	− 0.42	9 18 45.31	9 13 36.09	09.22	+0.12	09.34
W.	α Hydræ	−0.14	−0.05	− 0.35	9 26 43.55	9 21 34.50	09.05	+0.14	09.19
W.	10 Leonis Minoris	−0.02	−0.08	− 0.43	9 31 52.95	9 26 43.99	08.96	+0.16	09.12
E.	ο Leonis	−0.10	−0.08	+ 0.32	9 39 46.42	9 34 37.25	09.17	+0.18	09.35
E.	ε Leonis	−0.06	−0.09	+ 0.35	9 44 03.69	9 38 54.56	09.13	+0.19	09.32
E.	μ Leonis	−0.06	−0.10	+ 0.36	9 50 57.66	9 45 48.42	09.24	+0.21	09.46
E.	19 Leonis Minoris	−0.00	−0.13	+ 0.42	9 55 20.94	9 50 11.83	09.11	+0.22	09.33
E.	π Leonis	−0.10	−0.09	+ 0.32	9 58 54.20	9 53 44.98	09.22	+0.23	09.45
E.	η Leonis	−0.08	−0.11	+ 0.32	10 05 49.05	10 00 39.87	09.18	+0.25	09.43
E.	0 Camelopardalis	+1.03	−1.07	+ 2.44	10 21 20.94	10 16 11.38	09.56	+0.29	09.85
W.	30 Camelopardalis	+1.03	−0.74	− 2.70	10 21 20.73	10 16 11.38	09.35	+0.29	09.64

Chronometer fast at 8^h 30^m, chronometer-time 5^m $09^s.312$ (excluding slow stars.) Rate per chronometer-hour losing $0^s.156$.

	Collimation.	Deviation.
	s.	s.
δ Ursæ Minoris	+0.295, cl. E.	−0.222, W. of S.
λ Ursæ Minoris	+0.310, cl. E.	−0.203, W. of S.
76 Draconis	+0.318, cl. E.	−0.176, W. of S.
30 Camel	+0.293, cl. E.	−0.146, W. of S.
Mean	+0.304, cl. E.	−0.187, W. of S.

	Star.	Δa	Bb.	$C(\Delta i+abr+c.)$	t_0'	a	Δt	$r\rho$	$\Delta t'$
		s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.	m. s.
W.	76 Draconis, L. C	−4.68	+0.16	+1.88	8 55 56.28	20 51 13.30	−4 42.98	−0.11	−4 42.87
E.	76 Draconis, L. C	−4.68	+0.06	−1.62	8 55 57.17	20 51 13.30	43.87	−0.11	43.76
E.	κ Cancri	−0.41	+0.05	+0.26	9 05 51.13	9 01 07.00	44.13	−0.10	44.03
E.	ο Hydræ	−0.50	+0.05	+0.25	9 12 43.77	9 07 59.76	44.01	−0.10	43.91
E.	38 Lyncis	−0.09	+0.08	+0.32	9 15 57.93	9 11 13.69	44.24	−0.09	44.15
E.	40 Lyncis	−0.13	+0.08	+0.31	9 18 20.08	9 13 35.98	44.10	−0.09	44.01
E.	α Hydræ	−0.61	+0.04	+0.25	9 26 18.40	9 21 34.41	43.99	−0.08	43.91
E.	10 Leonis Minoris	−0.09	+0.09	−0.31	9 31 27.93	9 26 43.89	44.04	−0.07	43.97
W.	ο Leonis	−0.42	+0.06	−0.29	9 39 21.12	9 34 37.18	43.94	−0.06	43.88
W.	Leonis	−0.27	+0.07	−0.31	9 43 38.36	9 38 34.47	43.89	−0.06	43.83
W.	μ Leonis	−0.23	+0.09	−0.32	9 50 32.29	9 45 48.39	43.90	−0.05	43.85
W.	19 Leonis Minoris	−0.02	+0.12	−0.38	9 54 55.56	9 50 11.74	43.84	−0.04	43.76
W.	π Leonis	−0.44	+0.08	−0.28	9 58 28.90	9 53 44.93	43.97	−0.04	43.93
W.	η Leonis	−0.34	+0.10	−0.30	10 05 23.78	10 00 39.81	43.97	−0.03	43.94
W.	30 Camelop	+4.31	+0.46	−2.19	10 20 54.99	10 16 10.67	44.32	−0.01	44.31
E.	30 Camelop	+4.31	+0.11	+1.89	10 20 54.91	10 16 10.67	44.24	−0.01	44.23
E.	Carr. 3525, L. C	−5.75	−0.21	−2.04	10 59 47.62	22 55 03.18	44.44	+0.04	44.48
W.	Carr. 3525, L. C	−5.75	−0.28	+2.36	10 59 47.96	22 55 03.18	44.78	+0.04	44.82
W.	δ Leonis	−0.30	+0.07	−0.30	11 12 20.32	11 07 36.58	43.74	+0.05	43.79
W.	ξ Ursæ Majoris, med	−0.16	+0.08	−0.33	11 16 23.72	11 11 39.83	43.89	+0.06	43.95
W.	ο Leonis	−0.46	+0.06	−0.29	11 19 33.82	11 14 49.92	43.90	+0.06	43.96
W.	ι Leonis	−0.41	+0.07	−0.29	11 22 16.87	11 17 33.10	43.77	+0.06	43.83
W.	τ Leonis	−0.49	+0.06	−0.28	11 26 22.84	11 21 39.05	43.79	+0.07	43.86
W.	υ Leonis	−0.53	+0.07	−0.28	11 35 25.28	11 30 41.40	43.83	+0.08	43.91
E.	β Leonis	−0.37	+0.05	+0.26	11 47 33.52	11 42 49.62	43.90	+0.09	43.99
E.	β Virginis	−0.50	+0.04	+0.25	11 49 03.61	11 44 19.59	44.02	+0.10	44.12
E.	ο Virginis	−0.43	+0.05	+0.25	12 03 42.91	11 58 59.07	43.84	+0.11	43.95
E.	2 Carr., verr. Canum Venaticorum	−0.02	+0.09	+0.33	12 14 44.70	12 10 00.79	43.91	+0.12	44.03
E.	η Virginis	−0.52	+0.05	+0.25	12 18 23.01	12 13 39.16	43.85	+0.13	43.98
E.	6 Carr., verr. Canum Venaticorum	−0.05	+0.10	+0.33	12 24 34.21	12 19 50.39	43.82	+0.14	43.96
E.	20 Comæ	−0.30	+0.08	+0.27	12 28 18.89	12 23 35.23	43.66	+0.14	43.80
E.	32 Camelopardalis	+5.04	+0.04	+2.17	12 53 16.31	12 48 32.50	43.81	+0.17	43.98
W.	32 Camelopardalis	+5.04	+0.65	−2.50	12 53 15.34	12 48 32.50	42.84	+0.17	43.01

Chronometer fast at $10^h\ 30^m$, chronometer time, $4^m\ 43^s.932$, (excluding slow stars.) Rate per chronometer hour losing, $0^s.073$.

	Collimation.	Deviation.
	s.	s.
76 Draconis.	+0.303, cl. E.	−0.660, W. of S.
30 Camelop.	+0.247, cl. E.	−0.729, W. of S.
Carr 3525.	+0.223, cl. E.	−0.893, W. of S.
32 Camelop.	+0.192, cl. E.	−0.842, W. of S.
Mean.	+0.241, cl. E.	−0.781, W. of S.

Latitude.—Observer, Lieutenant Lockwood.

Station.	Date.	No. pairs.	Latitude.	P. E.
			° ′ ″	″
Saginaw, Mich	Sept. 19, 1876	26	43 25 07.606	
Saginaw, Mich	Sept. 21, 1876	26	43 25 07.574	
			43 25 7.590	±0.104
Saint Louis, Mich	Oct. 2, 1876	30	43 24 33.806	±0.164
Cairo, Ill	Dec. 2, 1876	20	36 59 48.421	
Cairo, Ill	Dec. 3, 1876	25	48.182	
Weighted mean			36 59 48.290	±0.096

SUMMARY OF RESULTS FOR AZIMUTH AT CAIRO, ILL.

Observer, Lieutenant Lockwood.

Date.	No. of results.	λ Urs. Min.	No. of results.	Polaris.	Remarks.
1877.		° ′ ″		° ′ ″	
Jan. 20			8	10 51 36.10	Instruments: 12-inch Troughton & Simms, and sidereal chronometer 1524.
23	8	10 51 34.84	8	30.67	
24	8	36.75			
27	8	36.36			
28	8	40.84	8	38.37	
28			8	35.02	
Mean each star		10 51 37.20		10 51 35.04	

	° ′ ″
Total mean giving equal weight to each star	10 51 26.12
Diurnal aberration	−0.31
Station Ohio west of north	10 51 35.81
Azimuth station Defiance—station Ohio	169 08 24.19

APPENDIX E.—MAGNETIC WORK.

1. REPORT OF LIEUTENANT CHARLES F. POWELL, CORPS OF ENGINEERS.

DETROIT, MICH., *May* 17, 1877.

MAJOR: I have to submit the following report of my work on the survey for the past year:

During the summer of 1876, while expecting orders for a change of station and duty, I was engaged in the office upon the partial computation of Captain Adams' time-work, exchange of signals for telegraphic longitude, and the performance of special duties assigned from time to time. On September 5, I was directed to proceed to La Crosse, Wis., Galena and Rockford, Ill., and Marshall, Mich., on magnetic work. The outfit which had recently been used by Lieut. T. N. Bailey, on the same duty at other points, and the detailed instructions given him concerning the number and accuracy of observations required, were transferred to me. The values of the magnets' scale-divisions, coefficients P and Q, and moment of inertia of the intensity magnet and stirrup, as determined by Lieutenant Bailey, were accepted. Constants, liable to change, were redetermined at each station.

Extreme care was exercised in the selection of sites for stations in order to avoid the effect of local attraction, and the required observations to attain that condition were always made. The results at Galena, however, may be looked upon with some suspicion. The lead abounding in that region is found imbedded in ferruginous clay, and has associated with it iron-ores in small quantities, and calamine (pyro-electric) in larger. The error in observations on account of torsion was reduced to a minimum and its correction determined. The field-work was completed on October 19.

During the following winter, I made the computations of my own observations, some additional ones of Lieutenant Bailey's, and the original computation of all of Lieutenant Lockwood's magnetic work. I was also engaged upon astronomical and other office-work.

The tabulation of all the results of magnetic work for the year, made by your direction, is appended. In the column of Table 4, "Differences between magnetic fore-sights and back-sights," showing results of examinations for local attraction, the lines A and B radiate from the magnetic post and include an angle of about 90°; they are from 300 to 600 feet in length.

The declination by magnet is the mean of the results at the elongations for one day, and, except the results in Lieutenant Bailey's work, with the small correction for hourly change applied according to the table of factors given in Lee's Tables and Formulæ. The daily values for horizontal intensities, except at Mount Forest, are independent—deflections having been immediately preceded, followed, or both preceded and followed, by oscillations.

At Mount Forest the mean of results from oscillations on two preceding days was combined with the angle given by each set of deflections.

Very respectfully, your obedient servant,

CHARLES F. POWELL,
First Lieutenant of Engineers.

Major C. B. COMSTOCK,
Corps of Engineers.

MAGNETIC WORK, 1876.

TABLE 1.—*Locations of stations and azimuth observations.*

Stations.	Latitude.	Longitude west of Greenwich.	Co-ordinates from—	Azimuth, W. of S.; △ – mark. Methods.	Results.
	° ′	° ′			° ′
Detroit, Mich....	42 20.0	83 03.1	Lamp-post at southwest corner of Clifford street and West Park Place, south 13° 06′.3 west;	Sun at noon.......	13 06.3
			Northwest corner of lake-survey building, south 26° 01′.0 west.	Sun at noon.......	13 06.3
Wabasha, Minn..	44 18.0	92 07.0	Southwest corner of Riverside House, 105 feet;	Polaris............	1 08.1
			Northwest corner of Riverside House, 58 feet.	Polaris............	1 08.1
La Crosse, Wis...	43 48.8	91 15.1	Southeast corner Main Street Park fence, north 43° 06′.7 west; 97.6 feet.	Equal altitudes of sun.	75 35.7
				Polaris............	75 34.5
Galena, Ill........	42 25.2	90 25.9	United States lake-survey astronomical post, 1873, south 72° 34′.8 east; 59.2 feet.	Polaris, e. e.......	1 42.0
				Astronomical post connection.	1 42.0
				Polaris, e. e.......	1 41.5
Rockford, Ill.....	42 17.0	89 06.6	East post at north corner of East Park fence, south 12° 24′.4 east; 210.2 feet.	Polaris, e. e.......	72 37.6
				Polaris, e. e.......	72 35.8
				Polaris, e. e.......	72 37.7
Marshall, Mich ..	42 16.4	84 57.8	United States lake-survey astronomical post, 1875, south 21° 18′.4 west; 95 feet.	Polaris, e. e.......	177 30.3
				Polaris, e. e.......	177 29.6
Mount Forest, Ill.	41 44.7	87 51.9	United States lake-survey astronomical post, 1876, north; 200 feet.	Polaris, e. e.......	26 54.3
				Polaris, e. e.......	26 55.4
Saginaw, Mich...	43 25.1	83 57.8	United States lake-survey astronomical post, 1876, northeast; 100 feet.	Polaris............	1 13.3
				Polaris, e. e.......	1 15.
Saint Louis, Mich.	43 24.5	84 36.2	United States lake-survey astronomical post, 1876, southeast; 150 feet.	Polaris............	93 50.4

TABLE 2: *Observers, instruments, &c.*

Stations.	Observers.	Instruments.	Scale-readings at magnetic axes. Declination-magnet.	Scale-readings at magnetic axes. Suspended-magnet.	Magnetic moment of deflector at 68° F.	
						Ft.
Detroit	Lieut. T. N. Bailey	Wurdermann's theodolite-magnetometer; Barrow dip-circle; pair of new, light magnets.	12.56	15.48	0.0998	r = 1.40
			12.50	15.53		
			12.53	15.41	0.0995	1.40
			12.53	15.47	0.0998	1.40
Wabasha	Lieut. T. N. Bailey		12.52	15.80	0.1004	1.00
			12.52	15.97	0.1003	1.33
					0.1000	1.00
			12.52	15.88	0.0999	1.33
La Crosse	Lieut. C. F. Powell		12.20	15.82	0.1005	1.33
			12.24	15.76	0.1004	1.00
			12.19	15.83		
					0.1002	1.00
					0.1002	1.33
			12.21	15.80		
Galena	Lieut. C. F. Powell		12.24	15.80	0.1003	1.00
			12.39	15.86	0.1002	1.33
			12.29	15.83		
			12.39	....	0.1004	1.00
					0.1004	1.33
			12.33	15.83		
Rockford	Lieut. C. F. Powell		12.31	15.99	0.1006	1.00
			12.44	15.76	0.1005	1.33
			12.42	15.70		
			12.38	15.82	0.1007	1.00
			12.26	....	0.1006	1.33
			12.36	15.82		
Marshall	Lieut. C. F. Powell		12.32	15.74	0.1008	1.00
			12.28	15.80	0.1007	1.33
			....	....	0.1008	1.00
					0.1007	1.33
			12.30	15.77		
Mount Forest	Lieut. D. W. Lockwood	Jones' declinometer; ? Troughton & Simms' dip-circle, declination-magnet X; deflector, D 5, and mirror-magnet.	38.77	....	0.2729	1.33
			38.65	....	0.2723	1.17
			38.87	....	0.2723	1.33
			38.77	....	0.2723	1.17
			38.76	....		
Saginaw	Lieut. D. W. Lockwood		(38.76)	....	0.2757	1.23
			....	....	0.2759	1.33
			....	....	0.2762	1.23
			....	....	0.2760	1.35
Saint Louis, Mich	Lieut. D. W. Lockwood		(38.76)	....	0.2769	1.23
			....	....	0.2767	1.35
			....	....	0.2775	1.23
			....	....	0.2775	1.35

TABLE 3: *Dates of principal observations.*

Stations.	Local attraction.	Declination by magnet.	Dip.	Intensity.	Azimuth.
	1876.	1876.	1876.	1876.	1876.
Detroit	May 18	June 3 6	May 24 25	June 3 5 6	May 31 June 1
Wabasha	Aug. 5	Aug. 8 9	Aug. 7 8	Aug. 11 12	Aug. 7 8
La Crosse	Sept. 15	Sept. 18 20	Sept. 18 19 21	Sept. 21 22	Sept.
Galena	Sept. 26	Sept. 29 30	Sept. 28 29	Sept. 28 29	Sept. 29 30 Oct. 1
Rockford	Oct. 7	Oct. 5 6 9	Oct. 6 9 11	Oct. 7 10	Oct. 7 9 10
Marshall	Oct. 14	Oct. 15 16 17	Oct. 16 17	Oct. 17 18	Oct. 14 17
Mount Forest	....	Aug. 26 28	Aug. 29 30	Sept. 1 2	Aug. 22 27
Saginaw	....	Sept. 20 21	Sept. 21 22	Sept. 16 18	Sept. 23 24
Saint Louis, Mich	....	Oct. 12 13	Oct. 14 15	Oct. 14 15	Oct. 11

TABLE 4: *Tests for local attraction and magnetic elements.*

Stations.	Middle dates, 1876.	Differences between magnetic fore-sights and back-sights.	Declination. By magnet.	Declination. By compass-needle.	Needle.	Dip. Single results.	Dip. Daily means.	Intensities. Horizontal.	Intensities. Horizontal.	Intensities. Total.
		° ′	° ′	° ′		° ′	° ′		*Feet.*	
Detroit	June 3	Line A—0 —02.0	0 04.8 east.		2	73 29.2		3.8965	r=1.40	
		B—0 —02.0			1	73 30.6	73 29.1			
								3.8991	1.40	
			0 04.6 east.		2	73 32.1				
					1	73 44.5	73 38.3	3.8986	1.40	
	Adopted		0 04.7 east.				73 33.3	3.8981		13.781
Wabasha	August 10	Line A—0 —02.9	8 04.6 east.	7 56.2 east.	1	74 24.4		3.7208	1.00	
		B—0 —00.4			2	74 15.3	74 19.9	3.7214	1.33	
			8 04.0 east.	7 55.0 east.	1	74 25.0		3.7264	1.00	
					2	74 21.6	74 23.3	3.7268	1.33	
	Adopted		8 04.3 east.				74 21.6	3.7238		13.814
La Crosse	September 20	Line A—0 —02.8	8 00.7 east.	7 47.3 east.	2	73 57.2	73 57.2			
		B—0 —01.2								
			8 00.7 east.		2	74 04.9		3.8435	1.33	
					1	74 04.5		3.8473	1.00	
					1	73 44.1	73 57.8			
					2	73 55.6		3.8447	1.00	
					2	73 54.3		3.8416	1.33	
					1	74 00.0	73 56.6			
	Adopted		8 00.7 east.				73 57.2	3.8443		13.907
Galena	September 29	Line A—0 —03.0	9 08.5 east.	8 57.3 east.	1	73 12.8		3.9953	1.00	
		B—0 —00.0			2	72 59.7	73 06.3	3.9985	1.33	
			9 08.9 east.	9 14.5 east.	1	73 12.2		3.9899	1.00	
					2	73 11.5	73 11.8	3.9865	1.33	
	Adopted		9 08.7 east.				73 09.0	3.9926		13.774
Rockford	October 9	Line A—0 —00.6	5 19.2 east.	4 58.9 east.	1	72 55.4		4.0799	1.00	
		B—0 —00.9			2	72 48.9	72 52.2	4.0831	1.33	
			5 16.6 east.		1	72 53.3		4.0832	1.00	

TABLE 4: *Tests for local attraction and magnetic elements*—Continued.

Stations.	Middle dates, 1876.	Differences between magnetic fore-sights and back-sights.	Declination.		Dip.			Intensities.		
			By magnet.	By compass-needle.	Needle.	Signal results.	Daily means.	Horizontal.		Total.
		° ′	° ′	° ′		° ′	° ′			
					2	72 36.0	72 44.7	4.0846	1.33	
			5—19.1 east		2	72 54.3				
					2	72 41.8	72 48.1			
	Adopted		5 18.3 east				72 48.3	4.0827		13.810
Marshall	October 17	Line A—0 —00.7 B—0 —01.0	1 43.9 east	1 23.2 east	1	73 34.3		3.9231	1.00	
					2	73 32.9	73 33.6	3.9210	1.33	
			1 40.8 east							
					1	73 30.4		3.9217	1.00	
			1 40.6 east		2	73 26.2	70 28.3	3.9273	1.33	
	Adopted		1 41.7 east				73 30.9	3.9233		13.826
Mount Forest	August 30		4 37.3 east	4 30.0 east	3	71 48.6		3.9730 3.9708	1.00 1.33	
			4 33.8 east		3	71 57.1		3.9710 3.9705	1.33 1.17	
	Adopted		4 35.6 east			71 52.8		3.9713		12.770
Saginaw	September 20		0 24.1 east		3	73 36.4		3.6724 3.6709	1.23 1.33	
			0 22.8 east		3	73 36.0		3.6709 3.6731	1.23 1.35	
	Adopted		0 23.4 east			73 36.2		3.6718		13.007
Saint Louis, Mich	October 14		1 00.4 east		3	73 48.0		3.6488 3.6513	1.23 1.35	
			0 56.9 east		3	73 49.8		3.6359 3.6369	1.23 1.35	
	Adopted		0 58.6 east			73 48.9		3.6432		13.070

2.—REPORT OF LIEUTENANT THOMAS N. BAILEY, CORPS OF ENGINEERS.

WABASHA, MINN., *August* 14, 1876.

MAJOR: I have the honor to submit the following report of magnetic observations, made under your direction by me at Detroit, Mich., and Wabasha, Minn.

The instruments used were Würdemann theodolite-magnetometer No. 3, Barrow dip-circle No. 26, Gambey sextant No. 1, and Bond mean time chronometer No. 201.

The magnets employed were new ones, sufficiently light to admit of suspension, without risk of breakage, by a single fiber of unspun silk.

The values of one division of the magnets were determined by observations upon different parts of the scales. No irregularities of divisions were detected. The temperature co-efficient of the long magnet was deduced from deflections at about 32° and 100° F.

The value of the co-efficient P depending upon the distribution of magnetism was found so small that it was neglected.

The moment of inertia of the long magnet and stirrup was obtained from loaded and unloaded oscillations; the load being a brass ring.

The instrumental corrections of the dip circle were neglected because of their small value.

Previous to selecting a station, observations were made to detect local attraction, bearings being taken with the magnetometer from the ends of two radii at right angles to each other and from 300 to 600 feet long.

At each station two results for azimuth were obtained, and two results for declination, each of the latter being the mean of the morning and afternoon elongations; torsion was carefully watched; in each case the torsion-bar was left suspended overnight before observing. As a check upon large errors, declination was also observed with a compass-needle.

At least two independent determinations of horizontal force were made: by oscillations and right-angled deflections at two distances.

Dip was observed on two days. Each time both needles were used with their poles direct and reverse; there being generally 160 readings with microscopes for each day's determination.

Care was taken during observations to remove to a safe distance all objects which might affect the magnets.

The approximate latitude of the station at Wabasha, by circum-meridian altitudes of the sun, is 44° 18′.

Descriptions of stations and other details will be found in my office-report and note-books.

It was intended that other points should be occupied during the summer, but while at Wabasha I received orders changing my station to West Point, N. Y.

Tables of results are appended.

Values of one division of scales.

	Long magnet.	Short magnet.
Individual results in minutes of arc	2.31	2.77
	.32	.75
	.30	.75
	.33	.80
	.33	.80
	.32	.74
	.31	.74
	.32	.75
	.32	.75
	.32	.74
	.32	.74
	.34	.75
	.33	.75
	.32	.75
	....	.75
	....	.75
Adopted value	2.32	2.75

	Temperature co-efficient of long magnet.
Individual results	0. 00045
	0. 00053
	0. 00048
	0. 00040
	0. 00044
	0. 00033
Adopted value...	0. 00044

	Moment of inertia of long magnet and stirrup at temp. = 68° F.
Individual results	2. 510
	. 506
	. 508
	. 512
	. 507
	. 514
	. 509
	. 522
	. 522
	. 517
Adopted mean...	2. 513
Log. K...........	0. 40014

Examinations for local attraction.

Difference between fore-sight and back-sight.

		°	′	″
Detroit, May 18........	Line A	00	02	00
Detroit, May 18	Line B	00	02	00
Wabasha, August 5....	Line A	00	02	52
Wabasha, August 5....	Line B	00	00	15

Positions of scale-zeros.

Date.	Temperature F.	Long magnet.	Short magnet.
	°		
Detroit, June 3	74	12. 53	15. 47
Wabasha, August 7......	86	12. 52	15. 88

Azimuth.	Determinations.			
Date.	Method.	Results.		
		°	′	″
Detroit, May 31	By sun at noon..	13	06	19
Detroit, June 1	By sun at noon..	13	06	15
Adopted results ...	....	13	06	17
Wabasha, August 7....	By Polaris	01	08	05
Wabasha, August 8....	By Polaris	01	08	07
Adopted results ...	....	01	08	06

Magnetic elements.

Date.	Dip.	Declination.	Horizontal intensity.	Total intensity.	Mag. moment of long mag. at 68° F.
	° ′	° ′ ″			
Detroit, June, 1876	73 30	00 04 49 E.	3.897	....	0.099
			3.899	....	0.100
Detroit, June, 1876	73 38	00 04 36 E.	3.899	13.781	0.100
Wabasha, August, 1876	74 20	08 04 37 E.	3.721	....	0.100
Wabasha, August, 1876	74 23	08 04 01 E.	3.726	13.814	0.100

Ranges in work.

	Ranges permitted by instructions.	Extreme ranges obtained at—	
		Detroit.	Wabasha.
Local attraction	05′	02′–00″	02′ 52″
Azimuth	02′	00′–04″	00′ 02″
Dip	10′	08′–00″	03′ 00″
Declination	10′	00′–13″	00′ 36″
Horizontal force	0.025	0.002	0.005

Very respectfully, your obedient servant,

THOMAS N. BAILEY,
Second Lieutenant of Engineers, U. S. A.

Major C. B. COMSTOCK,
Corps of Engineers, U. S. A.

APPENDIX F.—LEVELING OPERATIONS.

REPORT OF MESSRS. L. L. WHEELER AND F. W. LEHNARTZ, ASSISTANT ENGINEERS.

OFFICE UNITED STATES LAKE SURVEY,
March 31, 1877.

GENERAL: We have the honor to submit the following report on leveling operations during the summer of 1876 for determining the elevation of the great lakes above the level of the sea.

The plan of operations for determining the elevation of the lakes has been given in our report dated February 10, 1876. (See Annual Report of the Chief of Engineers for 1876, page 70, Part III.)

We were instructed to connect, during the past season, the bench-marks at Escanaba with those at Marquette by duplicate lines of levels, and for this purpose two parties were detailed and placed under our charge, each party consisting of a recorder and two men.

Work was commenced at bench-mark (1) at Escanaba August 11, and the bench-marks at Marquette were reached October 28.

The two parties worked together during the season.

The length of line leveled is 104.7 kilometers, (= 65 miles,) and the mean distance leveled per day for the days on which work could be done is 2.19 kilometers.

The parties were much delayed in the work by wind and unsteadiness of the atmosphere, and it was very seldom that work could be continued throughout an entire day.

The route followed was along the Chicago and Northwestern Railroad from Escanaba to U. S. B. M. 5, and along wagon-roads from that point to Marquette.

Throughout the season Mr. E. S. Davis acted as recorder for Assistant Engineer Lehnartz, and Mr. J. B. Johnson acted as recorder for Assistant Engineer Wheeler, and deserve much credit for the interest taken in the progress of the work.

The instruments used in this work were constructed by Kern, of Aarau, Switzerland, and were leveling-instruments Kern Nos. 1 and 2, and leveling-rods Nos. 2 and 3.

The leveling-instruments are alike in construction, and the same description applies to both.

The instrument is supported on the tripod by three foot-screws, and is fastened to it by a hook passing up through the triangular opening in the head of the tripod.

This hook is drawn downward by a coiled spring, which maintains a constant pressure on the leveling-screws.

One of the leveling-screws terminates in a sphere, which is firmly united to the frame of the tripod as a guard against accidents.

The instrument revolves about a vertical axis in the usual manner, and is provided with clamp and tangent-screw.

To the upper end of the vertical axis a horizontal bar is attached. Above this bar another bar is attached in such a manner that one end may be moved in a vertical direction by means of a slow-motion screw, or held immovable by a clamp-screw.

The other ends of the bars are joined in such a manner that two opposing screws act as pivots about which the vertical motion of the upper bar takes place.

These screws also permit a small lateral motion of that end of the upper bar.

The telescope is supported in wyes attached to the upper bar, which are closed by means of spring catches.

The diameter of the object-glass is $1\frac{7}{16}$ inches, the focal length $14\frac{1}{2}$ inches, and magnifying power of the telescope is 50 diameters.

The reticule is provided with one vertical and three horizontal wires.

The angular distance of the extreme wires from the middle wire was determined by readings taken on the rod at distances varying from 10^{m} to 100 metres.

The angular distance of the upper wire from the middle is, for No. 1, 17′ 33″; and for No. 2, 17′ 31″. And of the lower wire from the middle wire is, for No. 1, 17′ 42″; and for No. 2, 17′ 43″. And the distance between the extreme wires is, for No. 1, 35′ 15″; and for No. 2, 35′ 14″.

By means of these observations, tables were formed showing the distance of the rod from the instrument for any observed difference of the readings of the extreme wires on the rod.

The level is inclosed in a wooden case supported at the ends on wyes which rest on the pivots (rings) of the telescope, after the manner of the striding-level of an astronomical transit.

One of the wyes may be adjusted in a horizontal, and the other in a vertical direction, and from each project small steel pins which pass under the spring-catches fastening the telescope in the wyes. By raising the spring catches the level may be reversed on the telescope, thus determining the error of adjustment of the level, and the telescope reversed in its wyes, and by a combination of these two operations the inequality of the pivots may be determined.

Assistant-Engineer Lehnartz determined the inequality of the pivots by a series of observations, made in the Lake Survey Observatory, and found the pivot at eye-end of No. 1 to be 0″. 234 ± 0″. 046 larger, and of No. 2 to be 0″. 553 ± 0. 041 smaller than pivot at object-end of telescope. (Office report 668.)

The divisions of the level are etched on the glass tube, and the value of the divisions was determined by Lieut. T. N. Bailey, by means of a level-trier.

One division of No. 1 was found to have the value 4″.87, and of No. 2, 2″.15. (Office report 659.)

The upper portion of the level-case is of plate-glass, above which is a mirror moving on a hinge in such a manner that the observer may note the position of the level, his eye being near the eye-piece of the telescope.

The rods are constructed of well-seasoned fir-wood, and have a breadth of 8^{cm}., and thickness of $2.^{cm}5$.

They are strengthened by a strip of wood extending the length of the rods, having a breadth of 5^{cm}., and thickness of $2.^{cm}5$, attached to the rod in such a manner that a cross-section would be T-shaped.

The rods are divided into centimeters, the graduation extending three meters.

The value of the divisions of the rods was determined by Assistant-Engineer Wheeler by comparisons with the standard brass meter scale.

The mean length of a meter was found for rod No. 2 to be $999.^{mm}840$, and for No. 3 to be $999.^{mm}903$. (See office report No. 662.)

The rods have handles attached at 1 meter above the foot to aid in holding the rod, and a watch-level attached at 1.3 meters above the foot, for keeping the rod in a vertical position.

A plumb-line can also be attached for adjusting the watch-level.

The rod is supported on a cast-iron foot-plate while working, and is accompanied by a tripod, by means of which it can be held in a vertical position.

Before commencing work at any time a number of observations were made for determining the error of adjusted of the instrument.

For this purpose the rod is supported in its tripod in a vertical position, determined by the plumb-line and its level adjusted.

The collimation was then determined by noting the position of the three horizontal wires on the rod when the telescope was in its normal position, and when it was rotated 180° about its axis.

The collimation of the mean of the wires was thus determined, and was never allowed to exceed 2.mm5 for a distance of 100 meters.

The determination of the level-error (inclination) was made by reversing the level several times on the telescope, and was never allowed to exceed 2 divisions of the level.

The observations for collimation and inclination were usually repeated at the close of a day's work.

When working, the instrument was set up in such a position that the back-sight and fore-sight should be nearly equal, the difference in length of sights being limited to 10 meters.

The length of sight was not to exceed 100 meters. After having properly leveled the instrument, the observations were made in the following order: First the level was read, the tenths of the division being estimated; then the position of the three wires on the rod was noted, the millimeters being estimated; and, finally, the level was again read.

The recorder then took the difference between the readings of the middle and extreme wires to guard against errors, and if these differences denoted any error the observations were repeated.

Both parties connected with the same bench-marks when work was stopped for any cause, the bench-marks being usually spikes driven into the roots of stumps.

Two bench-marks were usually established and the elevation of each determined.

Whenever it was possible permanent bench-marks were established.

These bench-marks consist of a copper bolt 3 inches long and three-eighths inch diameter leaded into solid masonry or natural rock in a horizontal position. A small hole one-thirty-second in. diameter, drilled in the end of the bolt, is the point of reference.

A reduction of the observations was made at the end of each day's work, and a comparison of the two lines of levels made.

The original instructions were that when the discrepancy between the two lines of levels exceeded $5^{mm}\sqrt{\text{dist. in kilometers}}$, the line should be releveled.

This limit was subsequently extended to $10^{mm}\sqrt{\text{dist. in kilometers}}$ on account of difficulties met with in the work.

In reducing the observations, the mean of the readings of the three wires, the difference of the readings of the extreme wires and the difference of the sums of the two level readings were taken.

In a table constructed for the purpose and with the difference of the readings of the extreme threads as argument, the distance of the rod from the instrument was found.

In another table, with this distance and the difference of the sums of the level-readings as arguments, the correction for the inclination of the line of sight was found and applied to the mean of the readings of the three wires.

The sums of these corrected means for the back-sights and fore-sights were then found and their difference gave the difference of level between the bench-marks, subject to four corrections.

These corrections are for collimation, inclination, inequality of pivots, and absolute length of rod.

The collimation and inclination are assumed to be constant between two bench-marks, and the corrections to be applied to the difference of level due to these quantities, and to inequality of pivots, are found by means of the difference of the sums of the differences between readings of extreme wires.

The result was then corrected for absolute length of rod.

A reduction of the notes has been made in the office and compared with the field reduction, and the two reductions made to agree within 0.mm2.

The accompanying table contains the results of levelings between Escanaba and Marquette.

The first column contains a list of bench-marks. Where two bench-marks were established the mean of the two elevations is given; the second column the distance of each bench-mark from the preceding one; the third column the date of establishing the bench-marks; the fourth column the elevation as determined by Assistant-Engineer Lehnartz.

The fifth column shows the discrepancy between the two determinations of difference of elevation of consecutive bench-marks.

The sixth column contains the sum of these discrepancies, and the last column contains the adopted elevations, all determinations having equal weight.

Whenever a star appears in the fourth column three determinations of difference of elevation have been made and the mean applied to the elevation of the preceding bench-mark.

The elevations are given with reference to a plane 10.m000 below B. M. (1) at Escanaba.

The following permanent bench-marks were established:

U. S. B. M. (3)—Copper bolt leaded into masonry foundation of Escanaba light-house, west side of light-house, near northwest corner. It is 1.9791 meters below B. M. (1.)

U. S. B. M. (4)—Copper bolt leaded into natural rock on east side of Chicago and Northwestern Railroad, about 36 meters north of switch of siding leading to charcoal kilns at Maple Ridge, 38.9 kilometers from Escanaba. It is 111.4427 meters above B. M. (1) at Escanaba.

U. S. B. M. (5)—Copper bolt leaded into natural rock about 74 meters east and 53 meters south of switch at north end of siding at "Sands," 80.4 kilometers from Escanaba. It is 185.6593 meters above B. M. (1) at Escanaba.

U. S. B. M. (6)—Copper bolt leaded into third course of stones above water-table on north side of the Marquette, Houghton and Ontonagon Railroad general freight and ticket office at Marquette, about one foot from northeast corner. It is 5.4635 meters above B. M. (1 at Marquette.

B. M. (1)—At Escanaba is the top of the water-table of the large brick building of S. Adler, on the northwest corner of Ludington street and Douseman avenue, on the southeast corner of the building.

B. M. (1)—At Marquette is the southeast corner of the top of the foundation-stone of Grace Furnace. It is 5.1566 meters (=16.918 feet) above B. M. (1) at Escanaba.

B. M. (2)—At Marquette is a cross on the window-sill of the Marquette city water-works. It is on the center window, west side of building, and north side of window. It is 0.1550 meter below B. M. (1) at Marquette.

B. M. (3)—At Marquette is a cross on the window-sill of the Marquette city water-works. It is on the north window, east side of building, and 6 inches from the north end of sill. It is 0.1716 meter below B. M. (1) at Marquette.

Bench-marks.	Distance.	Date.	Elevation. (F. W. L.)	Partial excess.	Total excess.	Mean elevation.
	m.		*m.*	*mm.*	*mm.*	*m.*
Bench-mark (1), (Escanaba)	....	....	10.0000	....	....	10.0000
Reference Pt., (1)	1,221	Aug. 11	10.0048	− 2.5	− 2.5	10.0036
Reference Pt., (2)	1,366	Aug. 12	18.0441	+ 0.2	− 2.3	18.0430
Reference Pt., (3)	880	Aug. 15	13.2188	+ 0.6	− 1.7	13.2180
Reference Pt., (4 and 4*a*)	1,257	Aug. 15	11.0744	+ 4.1	+ 2.4	11.0756
Reference Pt., (5)	1,134	Aug. 16	13.6711	− 2.3	+ 0.1	13.6711
Reference Pt., (6 and 6*a*)	1,840	Aug. 16	33.0147	+ 1.6	+ 1.7	33.0155
Reference Pt., (7)	890	Aug. 17	41.9162	+ 1.6	+ 3.3	41.9178
Reference Pt., (8)	471	Aug. 19	43.6810	− 1.7	+ 1.6	43.6818
Reference Pt., (9)	366	Aug. 22	43.5151	− 0.2	+ 1.4	43.5158
Reference Pt., (10)	1,912	Aug. 23	45.9938	− 7.8	− 6.4	45.9906
Reference Pt., (11 and 11*a*)	1,059	Aug. 23	47.8321	− 1.1	− 7.5	47.8285
Reference Pt., (12 and 12*a*)	2,498	Aug. 28	50.9327	+ 1.6	− 5.9	50.9298
Reference Pt., (13)	792	Aug. 30	53.5598	+ 2.0	− 3.9	53.5579
Reference Pt., (14 and 14*a*)	1,832	Sept. 1	53.4649	+ 7.1	+ 3.2	53.4665
Reference Pt., (15 and 15*a*)	896	Sept. 2	55.3498	− 0.5	+ 2.7	55.3511
Reference Pt., (16 and 16*a*)	1,108	Sept. 2	55.6049	+ 0.2	+ 2.8	55.6063
Reference Pt., (17 and 17*a*)	1,356	Sept. 4	56.4752*	0.0	+ 2.8	56.4766
Reference Pt., (18 and 18*a*)	1,231	Sept. 5	55.7640	+ 2.6	+ 5.4	55.7667
Reference Pt., (19 and 19*a*)	1,802	Sept. 8	63.5001	+ 9.4	+14.8	63.5075
Reference Pt., (20 and 20*a*)	663	Sept. 8	65.7896	+ 3.9	+18.7	65.7989
Reference Pt., (21 and 21*a*)	1,842	Sept. 9	70.7336	+ 3.7	+22.4	70.7448
Reference Pt., (22 and 22*a*)	2,081	Sept. 9	78.8054	− 1.1	+21.3	78.8160
Reference Pt., (23 and 23*a*)	816	Sept. 11	81.8201	− 3.8	+17.5	81.8288
Reference Pt., (24 and 24*a*)	639	Sept. 12	82.4423	− 0.1	+17.4	82.4510
Reference Pt., (25 and 25*a*)	664	Sept. 13	87.5773	+ 1.5	+18.9	87.5867
Reference Pt., (26 and 26*a*)	3,134	Sept. 13	94.5868	− 8.7	+10.2	94.5919
Reference Pt., (27 and 27*a*)	967	Sept. 14	93.8875	− 1.7	+ 8.5	93.8917
Reference Pt., (28 and 28*a*)	1,395	Sept. 15	105.7050	+ 6.9	+15.4	105.7127
Reference Pt., (29 and 29*a*)	696	Sept. 15	105.4842	+ 1.3	+16.7	105.4925
Reference Pt., (30 and 30*a*)	636	Sept. 16	110.8863	+ 0.5	+17.2	110.8949
Reference Pt., (31 and 31*a*)	509	Sept. 18	116.3443	− 3.9	+13.3	116.3509
Reference Pt., (32 and 32*a*)	1,042	Sept. 19	122.5007	+ 3.3	+16.6	122.5090
United States bench-mark (4)	....	Sept. 19	....	....	....	121.4427
Reference Pt., (33 and 33*a*)	532	Sept. 19	119.5730	− 0.6	+16.0	119.5810
Reference Pt., (34 and 34*a*)	3,000	Sept. 20	126.7475	+ 1.3	+17.3	126.7561
Reference Pt., (35 and 35*a*)	1,822	Sept. 21	128.6519	− 0.1	+17.2	128.6605
Reference Pt., (36 and 36*a*)	1,304	Sept. 21	132.3445	− 5.6	+11.6	132.3503
Reference Pt., (37 and 37*a*)	1,622	Sept. 22	137.4919	− 0.9	+10.7	137.4972
Reference Pt., (38 and 38*a*)	2,185	Sept. 23	147.0789	+11.6	+22.3	147.0900
Reference Pt., (39)	1,449	Sept. 23	152.0032	− 5.8	+16.5	152.0114
Reference Pt., (40 and 40*a*)	1,583	Sept. 27	158.1228	+ 8.7	+25.2	158.1354
Reference Pt., (41 and 41*a*)	1,703	Sept. 27	163.2124	+ 1.8	+27.0	163.2259
Reference Pt., (42 and 42*a*)	1,822	Sept. 29	168.3666	+ 2.2	+29.2	168.3812
Reference Pt., (43 and 43*a*)	1,837	Oct. 1	171.4982	+ 4.6	+33.8	171.5151

Bench-marks.	Distance.	Date.	Elevation. (F. W. L.)	Partial excess.	Total excess.	Mean elevation.
	m.		*m.*	*mm.*	*mm.*	*m.*
Reference Pt., (44 and 44*a*)	1,237	Oct. 2	171.8808	+ 1.7	+35.5	171.8985
Reference Pt., (45 and 45*a*)	3,405	Oct. 4	167.6531	+ 2.6	+38.1	167.6721
Reference Pt., (46 and 46*a*)	1,730	Oct. 5	170.9992	+ 0.4	+38.5	171.0184
Reference Pt., (47 and 47*a*)	547	Oct. 7	171.6595	+ 1.5	+40.0	171.6795
Reference Pt., (48 and 48*a*)	2,267	Oct. 7	172.3327	− 1.0	+39.0	172.3522
Reference Pt., (49 and 49*a*)	636	Oct. 11	173.9393	− 3.4	+35.6	173.9571
Reference Pt., (50 and 50*a*)	1,084	Oct. 11	175.2747	− 3.3	+32.3	175.2908
Reference Pt., (51 and 51*a*)	1,576	Oct. 12	177.8297	+ 6.6	+38.9	177.8491
Reference Pt., (52 and 52*a*)	3,497	Oct. 12	182.6717	+ 2.9	+41.8	182.6926
Reference Pt., (53)	3,432	Oct. 13	189.7079*	0.0	+41.8	189.7288
Reference Pt., (54 and 54*a*)	2,289	Oct. 13	191.6421*	0.0	+41.8	191.6630
United States bench-mark (5)	943	Oct. 17	195.6399	− 3.0	+38.8	195.6593
Reference Pt., (56 and 56*a*)	2,045	Oct. 18	203.4268	− 5.3	+33.5	203.4435
Reference Pt., (57 and 57*a*)	2,706	Oct. 19	190.6291	− 3.5	+30.0	19[illegible].6441
Reference Pt., (58 and 58*a*)	292	Oct. 20	187.[illegible]97	− 0.6	+29.4	187.8044
Reference Pt., (59 and 59*a*)	2,662	Oct. 21	165.8070	− 0.1	+29.3	165.8216
Reference Pt., (60 and 60*a*)	2,437	Oct. 22	77.1220	+ 1.7	+31.0	77.1375
Reference Pt., (61 and 61*a*)	2,432	Oct. 23	48.2671	− 2.3	+28.7	48.2815
Reference Pt., (62 and 62*a*)	1,024	Oct. 24	36.8882	− 1.7	+27.0	36.9017
Reference Pt., (63 and 63*a*)	1,027	Oct. 25	29.4983	+ 1.1	+28.1	29.5123
Reference Pt., (64)	1,977	Oct. 26	19.9638	+ 0.2	+28.3	19.9779
Reference Pt., (65 and 65*a*)	4,500	Oct. 27	19.1682	+ 3.1	+31.4	19.1839
Bench-mark (1), Marquette	3,081	Oct. 28	15.1409*	0.0	+31.4	15.1566

Bench-mark (1) at Marquette, is 5.1566 meters (= 16.918 feet) above bench-mark (1) at Escanaba, and is 104.7 kilometers (= 65 miles) distant from it.

In forming the mean elevations all determinations are given equal weight.

* Wherever a star appears in the fourth column, three determinations of difference of elevation have been made, and the mean applied to the elevation of the preceding bench-mark.

MEAN SURFACE OF LAKE SUPERIOR ABOVE MEAN SURFACE OF LAKE MICHIGAN.

	Feet.
Mean surface of Lake Michigan from January 1, 1860, to December 31, 1875, inclusive, below bench-mark (1) at Escanaba, (office 291)	11.73
Bench-mark (1) at Marquette above bench-mark (1) at Escanaba, (see table,) 5.1566 meters	16.92
Mean surface of Lake Michigan, as above, below bench-mark (1) at Marquette.	28.65
Bench-mark (1) at Marquette above mean surface of Lake Superior from January 1, 1871, to December 31, 1875, inclusive, (office 291)	8.15
Mean surface of Lake Superior from January 1, 1871, to December 31, 1875, inclusive, above mean surface of Lake Michigan from January 1, 1860, to December 31, 1875, inclusive	20.50

L. L. WHEELER,
F. W. LEHNARTZ,
Assistant Engineers.

General C. B. COMSTOCK,
Superintendent United States Lake Survey.

APPENDIX G.—REDUCTION OF WATER-LEVEL OBSERVATIONS.

REPORT OF MR. O. B. WHEELER, ASSISTANT ENGINEER.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, Mich., May 17, 1877.

GENERAL: I have the honor to submit the following report on the reduction of water-level observations made since June 1, 1876, in continuation of Appendix H of the last annual report.

The water-level observations have been continued at the following ten stations. viz, Charlotte and Sacket's Harbor, on Lake Ontario; Cleveland and Erie, on Lake Erie; Detroit, on Detroit River; Milwaukee, Port Austin, and Escanaba, on Lakes Michigan and Huron; and Sault Ste. Marie and Marquette, on Lake Superior.

For the method of observation and reduction, for description of bench-marks, reference-planes, and zeros of gauges, and for tables from which the curves herewith given, up to June, 1876, are plotted, see Appendix H of last annual report.

The following new bench-marks and zeros of gauges have been established within the year:

Bench-mark (5) *at Milwaukee.*—A cross (×) on the masonry of the Kilbourn grist-mill at foot of Poplar street. It is cut in the stone 10¼ inches from the southeast corner on the east wall, and about 3 feet above the surface of the ground. It is 2.64 feet below bench-mark (1), and 5.69 feet above the plane of reference for Lake Michigan.

Bench-mark (3) *at Escanaba.*—The small hole in the center of a copper bolt leaded into masonry foundation of Escanaba light-house, west side of light-house, near northwest corner. It is 6.49 feet below bench-mark (1), and 2.15 feet above plane of reference for Lake Michigan.

Bench-mark (4) *at Marquette.*—The small hole in the center of a copper bolt leaded into third course of stones above water-table on north side of the Marquette, Houghton, and Ontonagon Railroad general freight and ticket office, about one foot from northeast corner. It is 17.93 feet above bench-mark (1), and 23.10 feet above the plane of reference for Lake Superior.

Zero of gauge at Cleveland.—The new zero of gauge used since September 1, 1876, is the upper surface of a five-inch spike driven into the side, near the end, of a cross-timber of the dock at the foot of Superior street. It is 1.39 feet below the old zero, and 1.55 feet above the plane of reference for Lake Erie.

The relative elevations at each station of the zero of gauge, check-point, and bench-marks have been redetermined within the year, and the following changes found necessary for the referring of zeros of gauges to reference-planes:

Zero of gauge at Sacket's Harbor.—It is now 2.75 feet below bench-mark (1), or 0.23 foot instead of 0.28 foot, as reported last year, above the plane of reference for Lake Ontario.

Zero of gauge at Escanaba.—It is now 7.88 feet below bench-mark (1), or 0.76 foot, instead of 0.78 foot, as reported last year, above the plane of reference for Lake Michigan.

Mean monthly water-levels for the several stations in feet and decimals below planes of reference.

(Continuation of tables in Appendix H, Report for 1876.)

Stations.	1876.							1877.				
	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.
Charlotte	0.56	0.54	0.96	1.62	1.96	2.30	2.56	2.96	3.19	3.07	2.46	.....
Sacket's Harbor	0.59	0.50	0.95	1.54	1.87	2.29	2.47	2.91	3.16	3.10	2.50	.....
Cleveland	0.59	0.70	1.00	1.17	1.70	1.62	1.96	.....	2.52	2.75	2.32	.....
Erie	0.51	0.54	0.90	1.19	1.40	1.48	1.69	2.30	2.52	2.55	2.34	.....
Detroit	0.79	0.57	0.74	0.95	1.45	1.48	*1.72	*1.01	*2.38	3.85	2.36	.....
Milwaukee	1.54	1.20	1.27	1.32	1.90	1.80	2.27	2.41	2.40	2.40	2.02	.....
Escanaba	1.53	1.20	1.20	1.45	1.90	1.90	2.22	.....	.....	.....	2.18	.....
Port Austin	1.59	1.17	1.20	1.46	1.92	2.03	2.16	2.43	2.49	2.51	2.48	.....
Sault Ste. Marie	2.01	1.61	1.57	1.53	1.87	2.15	2.63	2.92	2.90	3.01	3.14	.....
Marquette	1.89	1.50	1.39	1.50	1.83	1.99	2.27	2.63	2.87	3.13	3.21	.....

* River dammed up by ice, anchored on the bottom, below the city.

ESCANABA.

Mean monthly water-level in feet and decimals below plane of reference for Lake Michigan.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1874	.....	.....	.....	.....	2.78	2.56	2.51	2.53	2.72	3.04	3.27	.....
1875	.....	.....	.....	.....	3.04	2.82	2.78	2.72	2.80	2.93	3.06	.....
1876	.....	.....	.....	.....	2.05	1.53	1.20	1.20	1.45	1.90	1.90	2.22
1877	.....	.....	.....	2.18	.....	.....	.....	.....	.....	.....	.....	.....

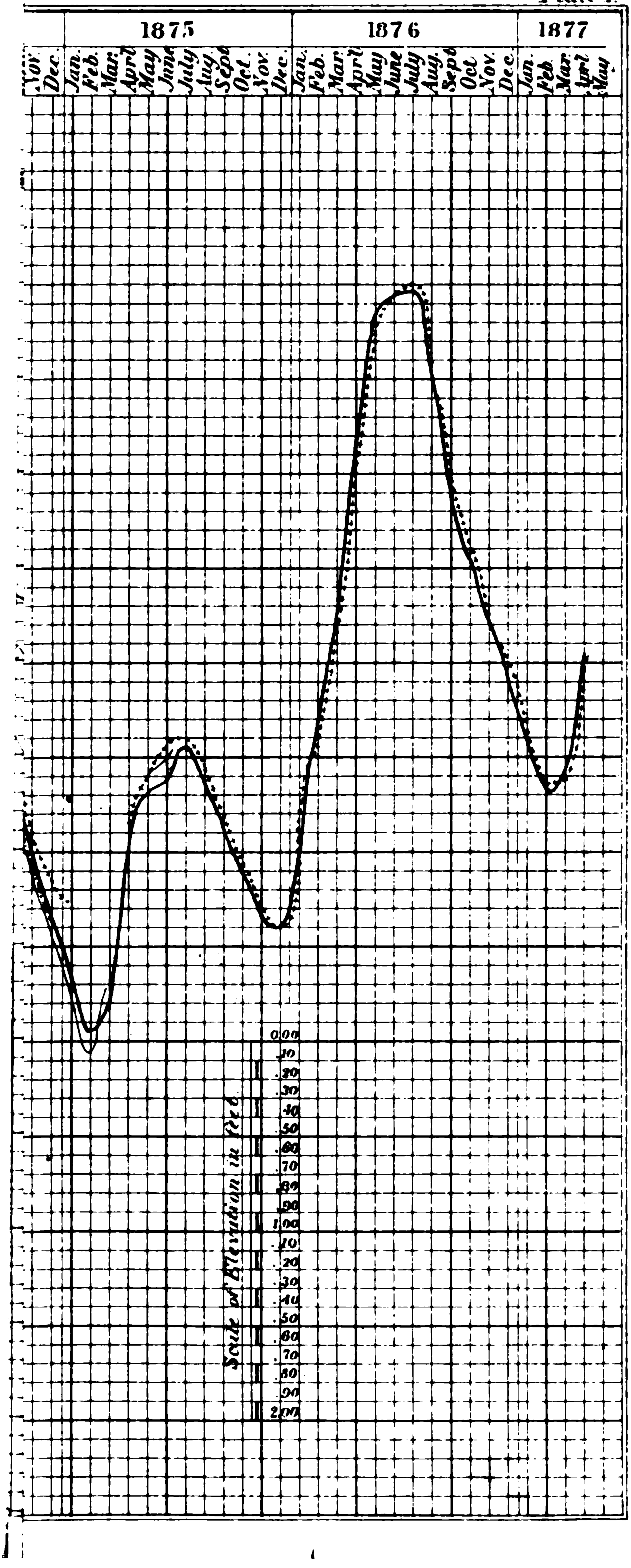
Office reports Nos. 291, 466, 642, and 762 have been used in obtaining data for this report.

Very respectfully, your obedient servant,

O. B. WHEELER,
Assistant Engineer.

General C. B. COMSTOCK,
Superintendent United States Lake Survey.

Plate I.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1876
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April
May
Scale of Elevation in Feet
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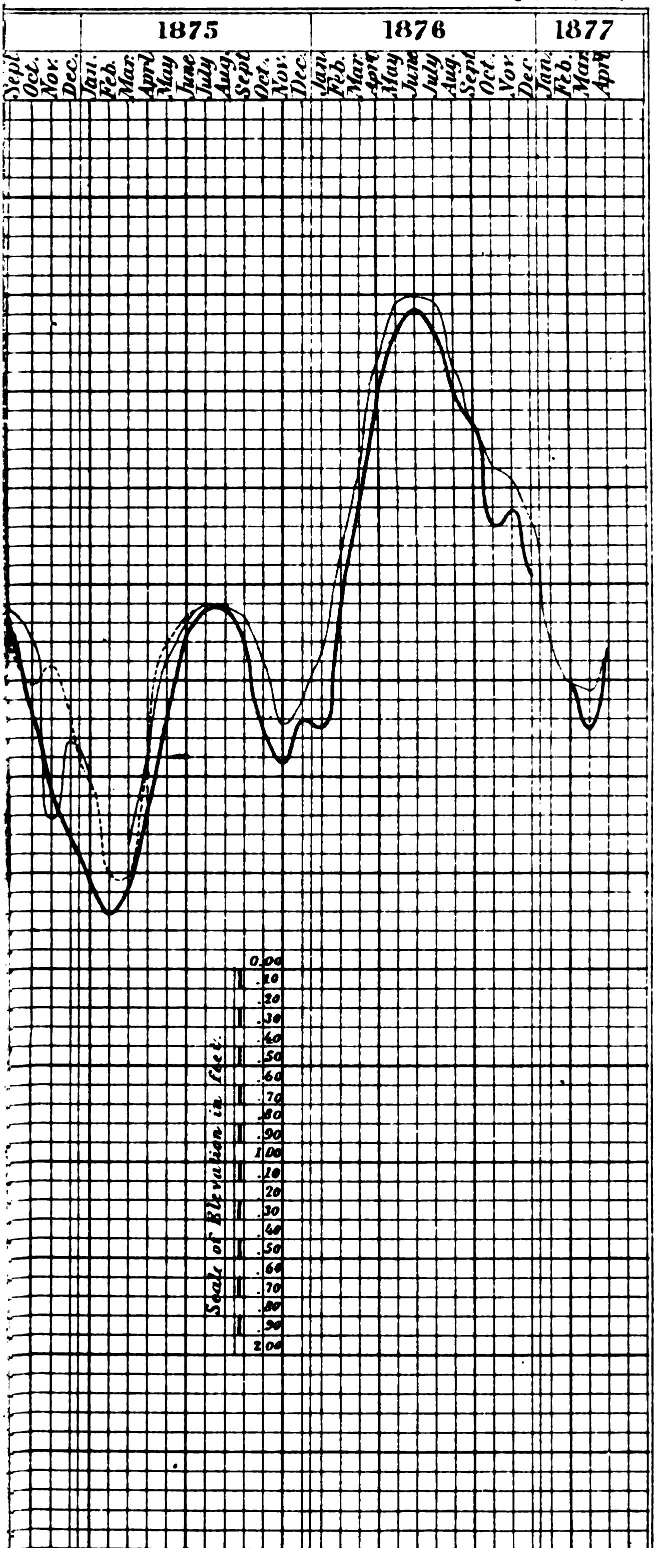
.90
2.00

Platt. II.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Feb.
Mar.
April
Scale of Elevation in feet.
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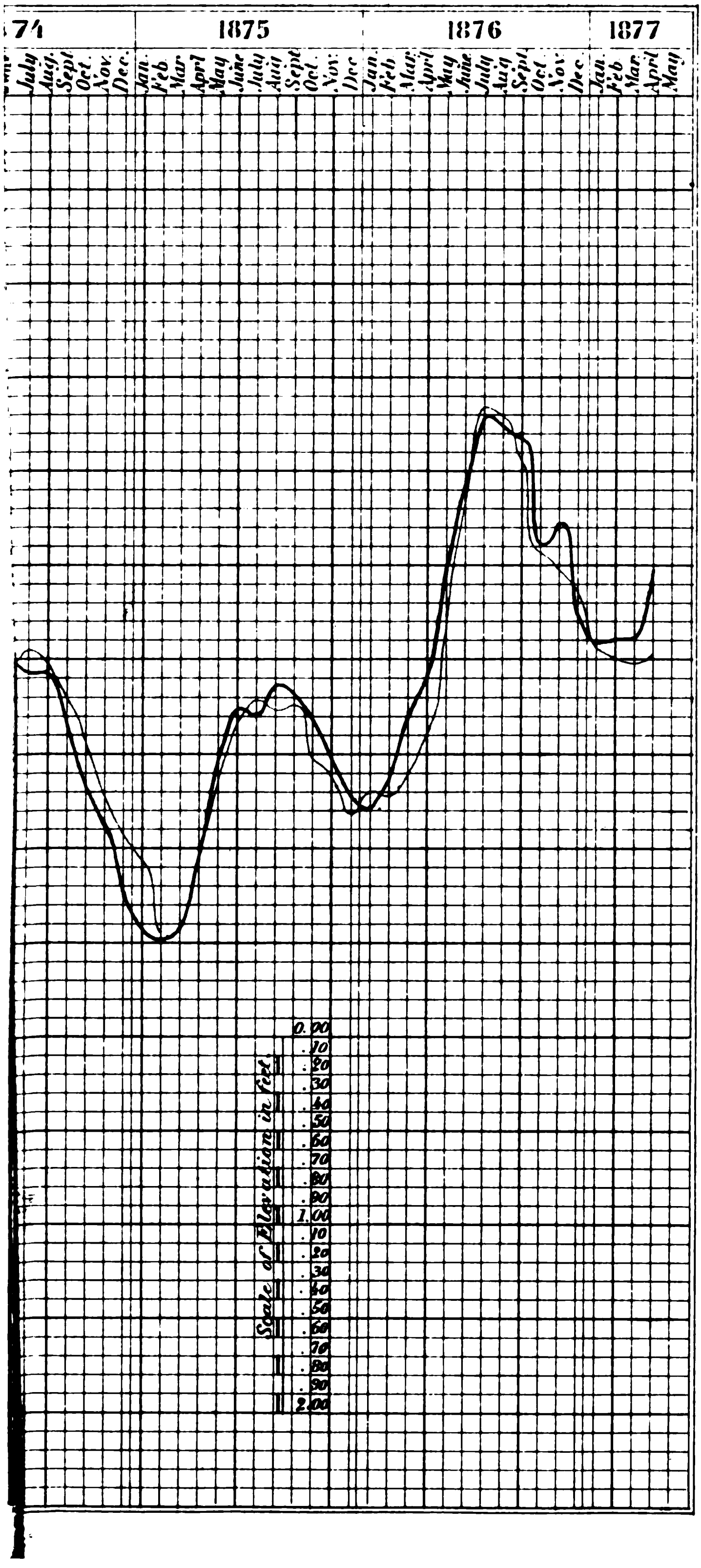
.90
2.00

Plate III.


74
1875
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1877
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Scale of Elevation in feet.
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2.00

APPENDIX H.—CHARTS.

1. LIST OF PUBLISHED LAKE-SURVEY CHARTS, JUNE 1, 1877.

Number.	Name of chart.	Scale.	Year of publication.
1	Lake Erie	1-400,000	1852
2	West End Lake Erie	1-120,000	1852
3	Kelley's and Bass Islands, Lake Erie	1-50,000	1852
4	Straits of Mackinac	1-120,000	1856
5	East Neebish Rapids, Saint Mary's River	1-15,000	1854
6	Saginaw River	1-10,000	1856
7	Saint Clair Flats	1-32,000	1857
8	Buffalo Harbor	1-30,000	1857
9	Tawas Harbor, Lake Huron	1-16,000	1857
10	Beaver Island Group, Lake Michigan	1-120,000	1855
11	Eagle Harbor, Lake Superior	1-5,000	1858
12	Agate Harbor, Lake Superior	1-10,000	1858
13	River Saint Mary, No. 1	1-40,000	1858
14	River Saint Mary, No. 2	1-40,000	1858
15	Maumee Bay, Lake Erie	1-30,000	1858
16	Eagle River, Lake Superior	1-10,000	1859
17	Ontonagon Harbor, Lake Superior	1-16,000	1859
18	Saginaw Bay, Lake Huron	1-120,000	1860
19	Thunder Bay, Lake Huron	1-40,000	1860
20	Marquette Harbor, Lake Superior	1-50,000	1860
21	Presque Isle and Middle Island, Lake Huron	1-40,000	1860
22	Lake Huron	1-400,000	1860
23	South End Lake Huron	1-120,000	1861
24	Grand Island, Lake Superior	1-25,000	1862
25	West End Lake Superior	1-32,000	1863
26	Grand and Little Traverse Bays, Lake Michigan	1-120,000	1863
27	North End Green Bay	1-120,000	1864
28	Copper Harbor, Lake Superior	1-10,000	1866
29	L'Anse and Keweenaw Bay, Lake Superior	1-30,000	1866
30	Portage Lake and River	1-30,000	1865
31	Lake Superior, No. 1	1-400,000	1872
32	Lake Superior, No. 2	1-400,000	1870
33	North End of Lake Michigan	1-400,000	1867
34	Huron Islands	1-30,000	1869
35	South End of Green Bay	1-120,000	1864
36	Lake Superior, No. 3	1-400,000	1873
37	Saint Clair River	1-40,000	1872
38	Isle Royale, Lake Superior	1-30,000	1872
39	Mouth of Detroit River	1-20,000	1874
40	City of Chicago	1-20,000	1874
41	Lake Saint Clair	1-50,000	1874
42	Saint Lawrence River, No. 1	1-30,000	1874
43	Sandusky Bay	1-20,000	1874
44	Saint Lawrence River, No. 2	1-30,000	1875
45	Saint Lawrence River, No. 3	1-30,000	1875
46	Saint Lawrence River, No. 4	1-30,000	1876
47	Sand Beach Harbor of Refuge, Lake Huron	1-8,000	1876
48	Niagara Falls	1-10,000	1876
49	Saint Lawrence River, No. 5	1-30,000	1876
50	South End Lake Michigan	1-400,000	1876
51	Coast-chart No. 5, Lake Michigan	1-80,000	1876
52	Coast-chart No. 3, Lake Michigan	1-80,000	1876
53	Saint Lawrence River, No. 6	1-30,000	1876
54	Coast-chart No. 2, Lake Michigan	1-80,000	1877
55	Coast-chart No. 1, Lake Michigan	1-80,000	1877

2. TABLE SHOWING THE ANNUAL ISSUE OF CHARTS OF THE NORTHERN AND NORTH-WESTERN LAKES.

Prior to October 1, 1857	2,500
October 1, 1857, to October 1, 1858	1,675
October 1, 1858, to October 1, 1859	2,600
October 1, 1859, to October 1, 1860	4,890
October 1, 1860, to October 1, 1861	3,254
October 1, 1861, to October 1, 1862	5,245
October 1, 1862, to October 1, 1863	4,084
October 1, 1863, to October 1, 1864	3,283
October 1, 1864, to October 1, 1865	2,589
October 1, 1865, to July 1, 1866	2,082
July 1, 1866, to July 1, 1867	5,464
July 1, 1867, to July 1, 1868	6,354

July 1, 1868, to July 1, 1869	5,634
July 1, 1869, to July 1, 1870	4,597
July 1, 1870, to July 1, 1871	5,328
July 1, 1871, to July 1, 1872	3,649
July 1, 1872, to July 1, 1873	5,546
July 1, 1873, to July 1, 1874	7,701
July 1, 1874, to July 1, 1875	5,039
July 1, 1875, to July 1, 1876	4,101
July 1, 1876, to July 1, 1877	2,736

3. LIST OF TRACINGS FURNISHED TO PARTIES FROM JULY 1, 1876, TO JUNE 1, 1877.

Name.	Date.	Locality.
W. S. Smith, C. E	July 22, 1876	Cross-section of Detroit River at Detroit, Mich.
William Brownlee & Co	Sept. 12, 1876	Vicinity of Adams Point, Lake Huron.
Maj. H. M. Robert, Corps of Engineers	Oct. 18, 1876	Vicinity of Bayfield, Lake Superior; vicinity of Ashland, Lake Superior.
Maj. W. McFarland, Corps of Engineers	Nov. 10, 1876	Vicinity of Sacket's Harbor, Lake Ontario, part of Cheaumont Bay, Lake Ontario.
Maj. G. Weitzel, Corps of Engineers	Apr. 27, 1877	East end of Manitou Island, Lake Superior.

APPENDIX I.—FIELD AND OFFICE WORK.

1. REPORT OF LIEUTENANT D. W. LOCKWOOD, CORPS OF ENGINEERS.

SURVEY OF THE MISSISSIPPI RIVER.

DETROIT, MICH., *May* 9, 1877.

SIR: I have the honor to make the following report of work done on the survey of the Mississippi River during the past winter. On October 26 I received orders to proceed to Saint Louis, Mo., and having received from Colonel Simpson, Corps of Engineers, the United States quarter-boat Arkansas, to take her to Cairo, Ill., and assume command of the parties there, quartering them on the boat.

Work was commenced on November 9. Lieutenant Price reported for duty to read angles. Assistant Engineer Towar had charge of building stations, topography, and hydrography. Assistant Engineer Teeple had charge of the leveling party.

The topographical parties were in charge of Recorders Russel and Hostetter.

During the season which closed February 6, 1877, 15 miles of river were surveyed, the work beginning at a point about two miles north of Cairo and extending south.

A base-line was measured with the secondary base apparatus on the Illinois Central Railroad to the north of the city, 5,400 feet long, (approximately,) and from it the triangulation was carried south about 7 miles and stations built for continuing it to the lower limit of the work. Fourteen stations were occupied in all, 10 by Lieutenant Price, 2 by Assistant Engineer Towar, and 2 by myself.

The leveling party ran a duplicate line of levels along the bank on the Missouri bank, connecting with the bench-marks of the levels of precision, and determined the heights of triangulation-points and the permanent reference-marks. These reference-marks are located in straight lines extending across the river, except at the upper limit of the work, where the line is broken at △ north base, one part extending across the Mississippi and the other across the Ohio River. The line crossing the Ohio includes the center-stone of △ Ohio. The first stones on these lines in Missouri and Kentucky are set one-half mile and the second 1¼ miles from the banks.

The second line is about 6 miles south of the first line, and runs nearly due east and west; it consists of four stones, two on either side of river. Those on the Missouri are respectively one-half and 1¼ miles back from the bank. On the Kentucky side the bluffs were reached at one-half mile, and the first stone is on the first bluff, the second stone is three-fourths of a mile farther back. The third line is 5 miles further down, and established in like manner as the second.

Topography was carried back to a distance of one mile from shore. Soundings were taken throughout the length of river surveyed.

CHARACTER OF BANKS.

Commencing at the upper limit of the work the Illinois bank of the Mississippi is bluff, and composed of fine silt. This bank is washing rapidly away. By comparing maps of previous surveys with that of the present one, the following results are found:

According to the survey made by Mr. Hely, of Cairo, (formerly county surveyor,) in 1874, the wash since then has been 558 feet.

From a survey made in 1865, by the same gentleman, the wash since then has been 656 feet. The old Government survey of 1809–'10 locates this bank 2,500 feet to the west of where it is now. The maps examined agree with each other, and that of the survey made last winter very closely, so far as the shore-line of the eastern side of the peninsula is concerned. The wash mentioned above gradually diminishes in amount to where the Government dikes are located.

The Missouri bank above station Missouri, and to near the station, is washing away from 6 to 10 feet a year ordinarily; it is composed of silt and fine sand, and this formation extends to a short distance below station Greenfield; in front of this station a bar is rapidly forming.

No wash between Greenfield and station Missouri. Specimens of sand from this bar and others forming near the shore, at different points, were examined with a microscope, with the following results:

10 per cent. less than 0.01 inch diameter.
50 per cent. less than 0.02 greater than 0.01.
40 per cent. less than 0.04 greater than 0.02.

The bar sand of the big bar in the Mississippi was about the same. The fine sand found in the silt, and along the Kentucky bank of the Ohio, was also examined with a microscope and found to be very uniform in size, and about 0.006 inch in diameter.

The bank from a short distance below station Greenfield to station Bird's Point is composed of silt, with seams of fine sand. At Bird's Point, the wash is from 50 to 75 feet per year. At station Bird's Ferry, not so great; about here the bank is being protected by the Illinois Midland Railroad Company, which has a "transfer" a short distance below the station.

On the Kentucky side of the Ohio the bank is gently sloping, composed of silt and fine sand, with no washing going on. This general character extends to a short distance above station Filmore, where the bank becomes steep and its composition changes to yellow clay, with very little sand. From here to about midway between station Willow Creek, station Island No. 1, the wash is about 10 feet per year; the formation of the bank remaining about the same.

There is no wash of the banks on the eastern side below station Island No. 1, or below Bird's Point on the western side, to the lower side of the river surveyed.

The material of the banks is silt, with occasional seams of fine sand.

CHARACTER OF BOTTOM.

From the northern end of the work in the Mississippi to the Government dike, a distance of two miles, the bottom is sand and gravel, the gravel varying from the size of a pea to an inch in diameter. The bars in this section are composed of sand and silt—90 per cent. being sand. From the improvement to the mouth of the Ohio the bottom is still sand and gravel, as before mentioned, for the upper section, except at a point 1¼ miles below the improvement, where one specimen of blue clay was found in mid-channel.

In the Ohio, from the head of the work to the mouth of the river, the bottom in the channel is gravel, varying in size from that of a pea to 1¼ inches.

Near the mouth of the river a conglomerate of cemented gravel is found, covering a small space near the Kentucky shore.

From the junction of the rivers to the lower limit of the work the bottom is sand, except near the head of Island No. 1, where the channel shows gravel with the sand. This continues to the end of the work.

Wherever the channel has been contracted by the falling of the river the bottom left bare was found to be of sand.

With this are submitted a map giving shore-line of the Cairo peninsula, from surveys made from 1809–'10 to the present day, and notes on boring, with section by Assistant Engineer Teeple.

For the proper equipment of a quarter-boat, I would suggest that each boat be provided with two skiffs (two pair oars) and one six-oared boat for sounding. The latter to be like those used on the river steamers. They differ from the L. S. cutters in being lighter and draw less water.

Very respectfully,

D. W. LOCKWOOD,
First Lieutenant, Corps of Engineers.

Major C. B. COMSTOCK,
Corps of Engineers, U. S. A.

BORINGS AT CAIRO, ILL.

The point chosen for boring was under the old pile-work of the Cairo and Saint Louis Railroad Company. It was thought this point was over the old bed of the Mississippi River and the frame-work would aid materially in the work.

Boring was begun on February 6, and progressed very well through 9 feet of silt, 21 feet of blue clay, and 4 feet of quicksand, when a mixture of sand and gravel was met. It was found that the pump would not wash out sand-grains more than three millimeters in diameter, so that it was necessary to remove the coarser gravel by some other means. A sheathed auger was tried, but without success, owing to the washing of the water in the pipe. A cartridge-auger was also tried and gravel of a centimeter in diameter was brought up, but it soon became evident that stones of larger size were in the pipe.

It was decided to drive the pipe to a depth of 43 feet below the platform, and by ramming plug it with the gravel inside. This was done, and then the pipe was drawn out, when it was found that with the exception of 1 foot at the bottom, which was clear, the pipe contained the gravel of the stratum passed. The maximum size of the coarse gravel was of three centimeters diameter, and an ounce in weight.

The steel plug was now put in and the pipe driven a few inches below the point before reached, when the plug being withdrawn it was followed 12 feet up the pipe by fine quicksand, showing that the gravel stratum had been passed.

The driving and washing now progressed well until a cottonwood log was met, at a depth of 57 feet below the platform and 33 feet below the zero of the engineer's gauge at Cairo. Pieces of this log were cut out by the pipe and washed to the surface. The pipe passed through one side of the log, which was judged to be about 6 inches thick.

From the gravel stratum mentioned above to a depth of 84 feet, that is, through a stratum of 42 feet, proved to be sand of very uniform fineness, the maximum size of grain being one millimeter in diameter. At this point gravel was again met, but before trying to fasten any of it in the pipe, the pipe was drawn out, the steel plug placed in position, and the pipe redriven. After the pipe had been driven to 87 feet below the platform, the plug was withdrawn, but it was found that the end of the pipe was still in coarse gravel, and as all efforts to replace the steel plug were futile it was decided to try the plugging of the pipe with gravel again. The pipe was therefore driven to a depth of 102 feet, at each 3 feet an examination being made to see if the pipe was filling below as fast as driven. These examinations showed 14 feet of filling in the pipe during the 15 feet driven.

An attempt was now made to draw the pipe, but it broke 18 feet below the platform. A shaft was immediately begun to dig for a new fastening, but it being necessary to crib the shaft, and the flow of water being considerable, the work progressed slowly. The pipe was reached and rejoined, but again parted at the same joint.

The lifting-clamp was then fixed on the section in the ground, and a chain made of ½-inch iron attached. After drawing a few inches the chain broke. It was again fastened, and again broke without lifting the pipe. On removing the clamp it was found that the strain of the chain having been a little one side of the pipe, it had bent it when clamped about its diameter, (2 inches.) It being impracticable to draw the pipe, it was abandoned.

It was evident that the gravel met at the depth of 84 feet below the platform, or 60 feet below the zero of the Cairo gauge, was quite coarse, as what entered the pipe was so large as to wedge the small wash-pipe tightly. It was estimated that gravel with a maximum diameter of four centimeters entered the pipe at a depth of 87 feet.

It is thought that the lowest section of the pipe turned from the right direction, and thus clinched and prevented the pipe from being withdrawn.

DEFECTS IN APPARATUS USED.

The apparatus used is well designed, and for borings where no gravel would be met would be in every way good for a depth of about 70 feet.

The defects in using at this point were as follows:

1st. Too short a fall for the hammers when new sections are first attached. The hammer-guides should be lengthened fully 4 feet. After reaching a depth of 70 feet it frequently took one hundred strokes of the hammer to drive the pipe 1 inch.

2d. The pump lacks strength and force, bursting at the junction of the brass cylinder and the casting above, and lacking force to wash out the coarse sand.

3d. The jack-screws proved too light, and twisted so as to be useless on drawing the pipe the second time.

4th. The steel plug cannot be inserted again after being withdrawn if the end of the pipe is in sand or gravel.

There should be added to the outfit a set of taps and dies for cutting threads on the pipes and in the collars.

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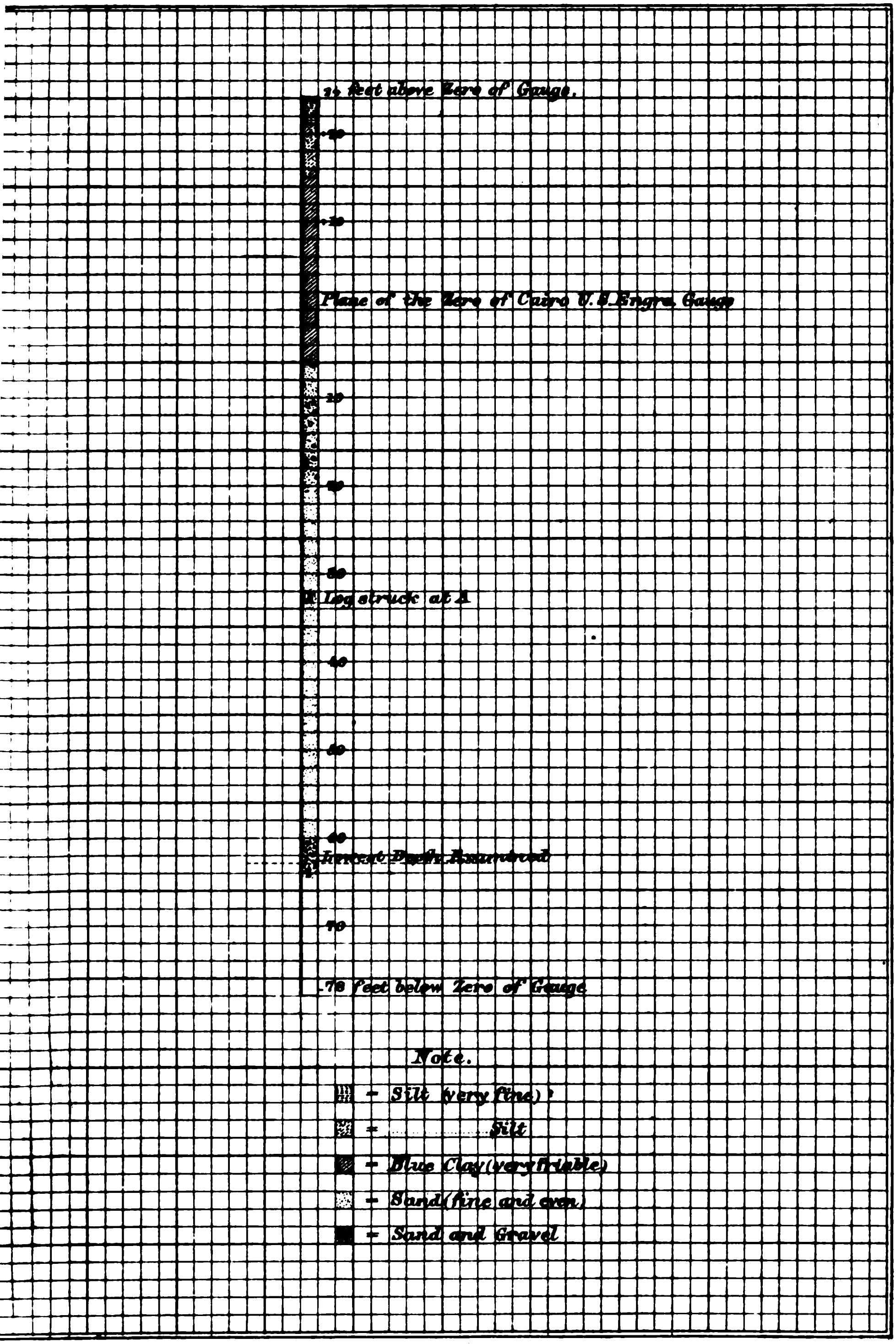
2. REPORT OF LIEUTENANT PHILIP M. PRICE, CORPS OF ENGINEERS.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, Mich., May 5, 1877.

SIR: I have the honor to submit the following report for the past year:

In June, 1876, I was placed in charge of the steamer Ada, with orders to continue the


14 feet above Zero of Gauge.
Plane of the Zero of Cairo U.S.Engrs. Gauge
10
20
30
Log struck at A
40
50
60
Lowest Depth Examined
70
78 feet below Zero of Gauge
Note.
= Silt (very fine)
= Silt
= Blue Clay (very friable)
= Sand (fine and even)
= Sand and Gravel

off-shore hydrography of Lake Erie from the point where it terminated the previous season, and to supply and move the shore-parties of Messrs. Mayer, Lamson, and Towar.

I left Detroit with the Ada on June 10, 1876, having on board the above shore-parties and their provisions, and proceeded to Erie, Pa., where the camp-equipage belonging to the shore-parties was stored. The steamer arrived at Erie on the 11th, and the work of supplying the parties and distributing them from Conneaut westward was immediately commenced, and was finished on the evening of the 12th.

Seven lines of soundings were run to fill a gap left in the off-shore hydrography of the season of 1875, between Conneaut and Erie, and the soundings were then carried from Conneaut westward nearly to Ashtabula Harbor, where, on June 23, I received orders from you to move the shore-parties and all Lake Survey property at Erie to Detroit in time to store the property and lay up the steamer by the night of June 29. This was done, and field operations were not resumed until August 4, 1876, on which date the steamer again left Detroit with the parties of Messrs. Lamson and Towar on board. These were landed on the south shore of Lake Erie, and the steamer immediately returned to Detroit for Mr. Terry's party, which was landed on the north shore of Long Point on August 8.

Twelve lines of soundings were run on the north and south sides of Long Point for the purpose of extending to the eastward the work of the previous year.

Six lines of soundings, extending across the lake, were made, the first being opposite Dunkirk and the last about 5 miles east of Ashtabula Harbor. These lines were about 15 miles apart, and their general direction was perpendicular to the axis of the lake.

On August 19 the off-shore work on the south side of the lake was resumed, and was carried as far westward as Vermillion, Ohio, by the close of the season.

The shore-parties were supplied with provisions and moved from camp to camp until the shore-line work was completed up to Vermillion on the 21st of October. On this date I commenced moving the parties and property to Detroit, and on the 27th the work of laying up the steamer for the winter was begun.

On the 31st of October I was ordered to proceed to Cairo, Ill., and report to Lieut. D. W. Lockwood for duty connected with the survey of the Mississippi River. I was employed on this duty until February 15, 1877, when I returned to Detroit. While on the Mississippi River I was mainly engaged in reading the angles of the secondary triangulation, an account of which will be found in Lieutenant Lockwood's report. The instrument employed was the repeating 10-inch theodolite Gambey No. 1.

I have reduced the field-notes and tabulated the results in the office-record.

During the summer season, on the steamer Ada, R. R. Bourland, A. O. Powell, and B. H. Colby were with me as recorders. On the Mississippi River work chainman George Beebe acted as my recorder.

Very respectfully, your obedient servant,

PHILIP M. PRICE,
First Lieutenant of Engineers.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

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3. REPORT OF MR. F. M. TOWAR, ASSISTANT ENGINEER.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, April 30, 1877.

MAJOR: I have to submit the following report of work done by the party under my charge since taking the field on June 10, 1876:

I left Detroit on June 10, 1876, on board the United States steamer Ada, with assistant engineers J. A. Ockerson, Walter Russel, and 18 men. We were placed in camp on the shore of Lake Erie, at a point midway between Conneaut and Ashtabula, Ohio, on the evening of June 11.

The work of surveying the adjacent shore-line, topography and hydrography, was at once commenced.

On June 24 I retured to Detroit, discharged the party, and on June 30 I was myself discharged from further duty until such time as an appropriation should be available for the further continuation of the survey. I was again employed on August 1, 1876, and after recruiting a party of 21 men, with Recorders Lightner and Hostetler as assistants, the party was placed in camp on August 5, at Madison, Ohio, and was successively transferred to Willoughby, East Rockport, Avon Point, and Vermillion, Ohio, on the following dates: to Willoughby, August 27; East Rockport, September 14; Avon Point, October 4; and to Vermillion, on October 12.

On October 21 the work was completed as far as the village of Vermillion, Ohio. The party was then moved by the steamer Ada to Detroit and discharged.

On September 1 Assistant Engineer A. T. Morrow joined the party at Willoughby,

was relieved on October 2, and again joined the party on October 10, remaining until the close of the season. On October 23 I was ordered to turn over my notes, field-sketches, &c., to Assistant Engineer Morrow, and report to Lieut. D. W. Lockwood, Corps of Engineers, for duty on a survey of the Mississippi River.

I was relieved from the above duty on February 10, 1877, and resumed charge of my Lake Erie work. The computation of this work had been nearly completed. I finished the computations and commenced platting and mapping the work. Since February 10 I have been assisted during the entire time by Mr. Morrow and during part of the time by Messrs. Pratt and Lehnartz. The work has all been platted on eight antiquarian sheets.

I am indebted to all the above-named gentlemen for valuable assistance.

The following table gives, in detail, the amount of work accomplished:

Miles of shore-line on lake	$56\frac{1}{4}$
Miles of shore-line on rivers	14
Square miles of topography	$38\frac{1}{4}$
Square miles of hydrography	50
Miles of chaining	97.5
Theodolite pointings	12,663
Theodolite readings	30,959
Elevations determined	5,837
Lines of sounding	424
Casts of lead	14,374
Sounding-stations built	33[illegible]
Triangulation-stations built	210
Buoys located	94
Base-lines chained	11
Triangles computed	73
Magnetic readings	261
Azimuths determined	18

Very respectfully, your obedient servant,

F. M. TOWAR,
Assistant Engineer.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

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4. REPORT OF MR. A. C. LAMSON, ASSISTANT ENGINEER.

UNITED STATES LAKE SURVEY OFFICE,
Detroit, Mich., May 1, 1877.

MAJOR: I have the honor to submit the following report in regard to the work done by the party under my direction during the season ending May 1, 1877:

In accordance with your instructions, I left Detroit on June 10, on board United States Lake Survey steamer Ada, for Ashtabula Harbor, Ohio, at which place I went into camp on June 12 with a party consisting of Assistant Engineer Terry, Recorder Morrison, and 18 laborers, and after completing the work assigned to me there I returned on June 27 to Detroit, at which place officers and men were discharged.

My party was re-organized on August 4, and consisted of Assistant Engineer J. A. Ockerson and Recorders Morrison and Paige and 21 laborers. I left Detroit on August 4, on board steamer Ada, for Red Creek, Ohio, at which place I went into camp August 5, and after completing the survey of the part of shore assigned to me there my camp was moved, on August 23, by steamer Ada to Fairport, Ohio, and on September 17 to Cleveland, Ohio, where I remained until October 28, the close of the season.

I reported to you on October 29, at Detroit, when my men were paid and discharged.

I am indebted to Assistant Engineers Terry, Ockerson, and Teeple and Recorders Morrison and Paige for valuable assistance in the field, and to Assistant J. A. Ockerson for faithful and careful work done in the office.

The following table shows the amount of field-work accomplished:

Azimuth-stations built	51
Sounding-stations built	229
Observations for azimuth	8
Pointings of theodolite	14,795
Readings of theodolite	23,416
Magnetic readings	76
Sextant angles measured	139
Buoys located	52
Casts of the lead	9,353

Miles chained	119
Square miles of topography	32
Square miles of hydrography	28
Shore-line, (miles)	31
River-shore line	28

During the winter season I made the computations of the co-ordinates of the azimuth stations and stakes.

The shore-line topography and hydrography were platted on five antiquarian sheets.

Very respectfully, your obedient servant,

A. C. LAMSON,
Assistant Engineer.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

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5. REPORT OF MR. FREDERICK TERRY, ASSISTANT ENGINEER.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, May 1, 1877.

MAJOR: I have the honor to submit the following report of work done under my charge during the year ending May 1, 1877:

I left Detroit, August 7, on board the United States steamer Ada, and was landed at Long Point, Ontario, on August 8. I remained at the point until August 28, when, having completed all the shore-line work it was proposed to have done there, I was moved by the United States steamer Ada to Glenville, Ohio, at which place I remained until October 3, making a survey of the shore from the city limits of Cleveland connecting with the work of Assistant Engineer Lamson to 10 miles to the east, where connection was made with the work of Assistant-Engineer Towar.

October 3 I was moved to Black River, Ohio, where a survey of 11 miles of the shore was made, connecting on both the east and west with work of Assistant Engineer Towar.

On October 23, the season's work having been completed, my party was conveyed by the United States steamer Ada to Detroit, where the men were discharged. I have reduced my work during the winter and it has been platted on seven sheets of antiquarian paper.

I was assisted in the field by Assistant Engineer Teeple from August 7 to September 28, and during the whole season by Recorders Darrow and Spitler. In platting my work I was assisted from March 7 to April 12 by Assistant Engineer Pratt. To all these gentlemen I am indebted for valuable aid.

In the following table I give the amount of work done, in detail:

Theodolite pointings	11,529
Theodolite readings	16,105
Casts of the lead	17,817
Triangulation stations built	52
Sounding-stakes built	226
Buoys placed	94
Square miles hydrography	33
Square miles topography	24
Shore-line, (miles)	33
Observations for azimuth	9
Magnetic observations	74

Very respectfully, your obedient servant,

FREDERICK TERRY,
Assistant Engineer.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

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6. REPORT OF MR. G. Y. WISNER, ASSISTANT ENGINEER.

OFFICE UNITED STATES LAKE SURVEY,
May 1, 1877.

GENERAL: I have the honor to submit the following report of field and office work accomplished by the triangulation-party under my direction since last annual report:

In accordance with your instructions, the party was organized May 16, 1876, with J. C. Eaton as recorder and T. Hockridge as observer's attendant, and commenced the measurement of angles of the main triangulation at Silver Creek, New York. The work at this station was completed June 7, after which the station at Westfield was occupied, but before the necessary measurements were obtained orders were received to return to Detroit, where the party arrived June 28, and on June 30 were discharged.

On August 3 the party was re-organized and occupied the station at Conneaut, Ohio.

Owing, however, to the lateness of the season, the water of the lake had become so warm that there was not sufficient refraction to allow signals being seen over the line from Conneaut to Houghton, and, consequently, the work at this station was abandoned on September 6. After leaving Conneaut the angles of the main triangulation at Erie Station, and secondary work at Erie, Miles' Grove, State line, Amboy, and Ashtabula, were completed, and on October 30 the party returned to Detroit.

After returning to the office I was occupied till January 1 with the reduction and compilation of my season's field-notes. Since then I have made and reported the computation of the following work, viz:

Lieutenant Lockwood's longitude observation at Mount Forest, Ill.; Saint Louis, Mich., and Saginaw, Mich., Lieutenant Lockwood's observations for personal equation; Captain Adams' observations for personal equation; Lieutenant Lockwood's observations for latitude of Saint Louis, Mich., Saginaw, Mich., and Cairo, Ill., and Assistant Flint's observations for latitude of Tonawanda, N. Y.

Very respectfully submitted.

GEO. Y. WISNER,
Assistant Engineer.

General C. B. COMSTOCK,
In charge of United States Lake Survey.

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7. REPORT OF MR. A. R. FLINT, ASSISTANT ENGINEER.

DETROIT, MICH., *May* 1, 1877.

GENERAL: I have the honor to report that during the year ending April 30, 1877, I was engaged on field and office duty as follows:

From May 1 until June 16, 1876, I was engaged in completing the computations and tables for difference of longitude between Detroit and Tonawanda, N. Y., and between Detroit and Mannsville, N. Y.

I also completed the reduction of the observations for relative personal equation between Lieut. D. W. Lockwood and myself.

From June 17 until June 30 I was engaged in inspecting triangulation-stations erected at Summit, Ill., and on Long Point, Lake Erie. The latter station was occupied for the purpose of reading the primary angles, but the weather proved to be very unfavorable, and nothing of consequence was accomplished before the parties were recalled from the field, June 30.

From August 2 until November 15 I was engaged on the primary triangulation of Lake Erie, occupying and completing the angles at Houghton, Edenboro', and Andover. One angle at Houghton, between Erie and Conneaut, was not read, as Conneaut is not in sight except during excessive refraction.

Owing to very unfavorable weather and to the lateness of the season when this station was occupied, no measurements of this angle were obtained.

The number of primary angles read at these three stations was 17.

After returning from field-work, November 15, I was engaged on office-computations during the remainder of the year, viz:

1st. In tabulating and reducing the primary angles read by Assistant Engineer Darling and myself during the season of 1876. This included the duplicate reduction of the target corrections and mean and probable errors of the angles.

2d. In connection with Assistant Engineer Wisner, in reducing, by method of least squares, the time-observations made by Lieut. D. W. Lockwood, at Willow Springs, Ill., and Detroit, in 1876.

Also, by method of high and low stars, the reduction of time-observations made at Saginaw and Saint Louis, Mich., by the same observer.

3d. In checking tables compiled by Capt. H. M. Adams, for difference of time between Detroit and the longitude stations occupied by Lieutenant Lockwood, including the personal equation at Detroit.

4th. Reduction of azimuth observations made by Lieutenant Lockwood at Cairo, Ill.

5th. Duplicate computation of length of secondary base-line, measured at Cairo, by Lieutenants Lockwood and Price.

Also, the computation of the triangles and co-ordinates of the secondary and tertiary stations about Cairo, Ill.

I was aided in the field-work by Mr. C. W. Clark, to whom my thanks are due for the efficient manner in which he discharged his duties as recorder.

Respectfully submitted.

A. R. FLINT,
Assistant Engineer.

General C. B. COMSTOCK,
Major of Engineers.

8. REPORT OF MR. R. S. WOODWARD, ASSISTANT ENGINEER.

OFFICE UNITED STATES LAKE SURVEY,
May 5, 1877.

SIR: I have the honor to present the following report on work done by me during the year ending April 30, 1877:

About May 1, 1876, I was assigned to duty in the primary triangulation of Lake Erie. Preparations were accordingly made and my party left Detroit for Angola, N. Y., on May 16. On May 18, we began work at Sturgeon Point station.

The theodolite used was the new one, No. 3, by Troughton and Simms, and owing to imperfections in its construction and changes that had to be made in the illuminating apparatus of the reading microscopes, the work at Sturgeon Point station was not completed until June 19.

On June 20 we moved to Grand River station, near Port Maitland, Ontario.

On June 23 I received orders to suspend work and return to Detroit. Accordingly, my instruments and equipage were shipped on June 24.

On June 30 I was discharged. On August 3 I was re-employed, and ordered to resume work at Grand River station. I arrived at this station August 4, but, as it was necessary to visit four other stations, set signals, and establish flashers, the work of reading angles was not begun till August 12.

Great difficulty was experienced in seeing over the line to Long Point, it being partly under water, with ordinary refraction, and as the weather was almost continually smoky, the measurements were delayed until September 22.

September 23 the party moved to Westfield station, near Westfield, N. Y.

At this station, in addition to the primary work, there was considerable secondary work to be done. Secondary stations Brockton, Prospect, Barcelona, Ripley, and Harbor Creek were occupied, and marking and reference stones were set at each. At Dunkirk, N. Y., a connection was made between the old and new light-house towers.

Rainy and windy weather prevailed during the remainder of September and throughout October, and, as a consequence, the work was not completed until November 4.

Returning to Detroit, on November 4, I was engaged till about January 1, 1877, in tabulating the results of the season's field-work, and computing connections for signals, &c.

Since January 1, I have been occupied chiefly as follows: In duplicate computations by least squares of the differences between the lengths and expansions of the Lake Survey brass yards; in the compilation of a descriptive catalogue of one hundred and four primary stations, in the triangulation extending from Minnesota Point base-line to the south end of Lake Michigan; in the tabulation of the observed values of the angles, the conditions for adjustment, the adjusted values of the angles, and other data derived from the triangulation connecting Minnesota Point base-line and the line Freemont-Deerfield, Ill.

Very respectfully,

R. S. WOODWARD,
Assistant Engineer.

General C. B. COMSTOCK,
Superintendent United States Lake Survey.

9.—REPORT OF MR. J. H. DARLING, ASSISTANT ENGINEER.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, April 30, 1877.

SIR: I have the honor to submit the following report of field and office work done by me during the year ending April 30, 1877:

Field-work.—I went into the field August 7, 1876, in charge of a triangulation party, and was engaged in measuring angles on the primary system of Lake Erie.

The first station occupied was Long Point. Here my progress was seriously hindered by cloudy weather and gales of wind, and by difficulty in seeing over the line to Grand River, which required extraordinary refraction to bring into view. I was detained at this point about two months. Then crossed the lake and occupied Station Thompson, in Ohio, completing the angles of this point and also the secondary work in that vicinity, after which I returned to Detroit, reaching the office November 18, 1876.

The instrument which I used was the new 14-inch Troughton and Simms theodolite lake-survey No. 4. The season was too short and the weather too unfavorable most of the time to afford a thorough test of its qualities; but the small range in the results on a few occasions, when the conditions for measurement were first class, encouraged

me to believe that the instrument (with the exception of some minor and easily-remedied defects) is a superior one.

Very respectfully, your obedient servant,

J. H. DARLING,
Assistant Engineer.

General C. B. COMSTOCK,
Superintendent United States Lake Survey.

10.—REPORT OF MR. O. B. WHEELER, ASSISTANT ENGINEER.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, Mich., May 15, 1877.

GENERAL: I have the honor to submit the following abstract of work accomplished to date by the computing division since June 26, 1876:

All computations not self-checking have been computed in duplicate.

1. *Triangulation.*—The completion of adjustment of primary triangulation from Sandy Creek base to line Tonawanda-Pekin, near Buffalo base, in one set of equations and formation of local and side equations for triangulation around Buffalo base from line Tonawanda-Pekin to line Grand River-Westfield. The method employed is that given in the lake-survey report for 1872. The computation in ten-place logarithms of sides of triangles between Keweenaw and Minnesota bases, and between Keweenaw and Fond du Lac bases, with Keweenaw base as unity, and of sides of triangles between Sandy Creek base and line Tonawanda-Pekin, with Sandy Creek base as unity.

The preliminary computation of the primary triangulation of Lake Erie from Buffalo to Ashtabula and computation of secondary triangulation, connecting primary triangulation with shore-line work through 21 points along shore.

2. *Geodetic positions and data for reduced charts.*—The computation for mapping purposes of 67 geodetic positions on Lake Ontario and of 41 on Lake Erie. The referring of 21 stations on Lake Ontario to meridians and parallels 10′ apart, 67 stations on Lake Ontario to meridians and parallels 30′ apart, and of 74 stations on Lake Michigan to meridians and parallels 5′ apart. The preparation of tables and notes for 6 final charts.

3. *Latitude, longitude, time, and azimuth.*—The check-computation of latitude of 6 stations in Ohio, Michigan, and Illinois; and of triangulation connecting stations with fixed points of reference. The making of 13 sets of time-observations, the reduction of 20 sets of observations for time at Detroit, the reading of chronograph-sheets for 18 nights' work, the computation of wire-intervals and the tabulation of results for time and longitude. The check-computation of azimuth at Cairo, Ill.

4. *Water-levels.*—The reduction of water-level observations made since May, 1876; the preparation for publication of tables of results, platting of curves, and description of new bench-marks.

5. *Base-lines.*—The recomputation of Minnesota base-line. The making of a synopsis of data and corrections for each of 5 primary base-lines. The solution of 4 sets of equations by least squares in connection with the comparisons of base-line tubes with yards and standard bar.

6. *Miscellaneous.*—The reading of proof-sheets of the last annual report. The examination of projections for 5 reduced charts and a final examination of 6 finished within the year; the comparison of 5 thermometers with 2 standards; the compiling of a tracing from land-surveys of the Mississippi River from Cairo to New Madrid; the extending of 3 progress-sketches showing work completed up to May 1, 1877; the winding and comparing of chronometers and tabulation of corrections and rates of standard chronometers at intervals of two weeks; the comparing, tabulating, and putting in form the results from all computations.

Various other check-computations have been made and data looked up and furnished parties as occasion required.

I have been faithfully assisted by Assistant Engineers Russell, Kummell, and Wright, regularly, and by Assistant Engineers Darling, Lehnartz, and L. L. Wheeler, while assigned to me.

Very respectfully, your obedient servant,

O. B. WHEELER,
Assistant Engineer.

General C. B. COMSTOCK,
Superintendent United States Lake Survey.

11.—REPORT OF MR. E. S. WHEELER, ASSISTANT ENGINEER.

DETROIT, MICH., *May* 1, 1877.

SIR: I have the honor to report the following work accomplished during the past year:

The permanent and temporary changes in the length of the tubes of the Würdemann base apparatus have been determined from all the comparisons since 1870.

The results of these changes have been computed and applied to the Minnesota, Fond du Lac, Keweenaw, Sandy Creek, and Buffalo bases.

The details have been given in special reports.

Comparisons of steel-yards A and B with each other were made during the month of November.

From the beginning of February until the present time I have been occupied in preparing the new comparing-room and determining the constants of the Repsold base apparatus.

Very respectfully, your obedient servant,

E. S. WHEELER,
Assistant Engineer.

General C. B. COMSTOCK,
Major of Engineers.

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12. REPORT OF MR. G. A. MARR, ASSISTANT ENGINEER.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, May 1, 1877.

GENERAL: I have the honor to submit the following report of field and office work since May 17, 1876:

With a party consisting of George C. Comstock as recorder, and John P. Hoffman as attendant, I left Detroit May 17, 1876, for Port Colborne, Ontario, to occupy primary station Sugar Loaf for measuring the angles at that station. From this point 7 stations were to be read to making 7 angles, as each angle was to be used directly in the system of primary triangles.

As 4 of 7 the stations to be read to were on the north shore of the lake it was necessary that I should put up the targets at these stations, both for use for Sugar Loaf station and also for the two parties on the south shore. This delayed the work for measuring angles until May 23, when all was in readiness to take advantage of the first favorable weather. Besides measuring the primary and secondary angles at the station, a base of 642 meters and a tertiary system of triangles were measured. The work at Sugar Loaf station was completed June 26, with following results:

Primary stations occupied	1
Primary angles measured	7
Secondary angles measured	4
Vertical angles measured	8
Tertiary stations occupied	4
Tertiary angles measured	12

In accordance with instructions, the party returned to Detroit on June 28, when the recorder and attendant were paid and discharged. Was occupied until the end of June turning in note-books and Lake-Survey property.

On August 1 received instructions to continue the reconnaissance for primary triangulation west from Cleveland, Ohio, and to locate secondary points from the State line between Pennsylvania and Ohio west as far as the location of points for primary triangulation was completed.

Was joined by Mr. George C. Comstock, as recorder, on August 3, and was occupied at the office until August 5 making plans and specifications for primary stations so as to obtain bids from parties in Cleveland for building primary stations in that vicinity.

Reached Cleveland on the morning of August 6, and was occupied two days in securing reliable contractors that would forward to the office bids for building stations.

The reconnaissance was then commenced, and the following points for primary stations selected, viz: Olmstead, Grafton, Elyria, Camden, Brownhelm, and Townsend.

This part of the work was quite difficult, on account of the very high timber in that section of country.

Secondary points, to be connected directly with the shore-work, were located as follows: Amboy, Saybrook, Steeple of Baptist church in Ashtabula, Geneva, Perry, pier-light and main light-house at Fairport, Euclid, and the following points in Cleve-

land: chimney of Otis Steel-Works, in the eastern part of the city, spire of the Presbyterian church, Bessemer-steel flag-pole, and Main light-house, in the central part; spire of Saint Malachi's church, (since blown down,) on the west side, and the light-tower of the water-works crib out in the lake; and also west of Cleveland; triangulation stake 32 of Assistant-Engineer Towar; Dover; light-house at Black River; light-house and two tall church-spires in Vermillion; light-house and spire of Presbyterian church in Huron; spire of Methodist church and cupola of court-house in Sandusky; Cedar Point light-house; and Marblehead light-house.

Also inspected and reported upon the following primary stations, built by Mr. Luke Crossley, viz: Conneaut, Andover, Orwell, Thompson, Mesopotamia, Claridon, Little Mountain, Chester, Willoughby, Warrensville, Royalton, and Rockport.

After returning to the office, November 25, the results for angles at Sugar Loaf station were reduced and tabulated, and target corrections carefully computed.

Made a computation by least squares of the comparisons of brass yard No. 6 with the steel yards A and B, and reduced from the original notes the comparisons of tubes and standard bar in the measurement of the Minnesota Point base, being a recomputation.

Also, checked a reduction by Assistant Engineer Pratt of comparisons of standard bar and secondary base tubes 3 and 4.

About March 7 was assigned to duty with Assistant Engineer E. S. Wheeler in the comparing-room.

When not occupied in observing and other necessary work in the room, was engaged in determining values of levels and microscopes of the Repsold base apparatus.

Was ably assisted during field-work by Mr. George C. Comstock, as recorder, and it affords me pleasure to recommend him for further and even more responsible employment.

Very respectfully, your obedient servant,

G. A. MARR,
Assistant Engineer.

General C. B. COMSTOCK,
Major of Engineers.

APPENDIX M M.

ANNUAL REPORT OF MR. CLARENCE KING, GEOLOGIST, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

GEOLOGICAL EXPLORATION OF THE FORTIETH PARALLEL, FROM THE SIERRA NEVADA TO THE EASTERN SLOPE OF THE ROCKY MOUNTAINS.

U. S. GEOLOGICAL EXPLORATION OF THE 40TH PARALLEL.
Cheyenne, Wyo., August 23, 1877.

GENERAL: I have the honor to report that for the year ending June 30, 1877, the operations of this survey have been entirely confined to office-work, consisting of the superintendence of the publication of our atlas and text. In July of the previous year, the Public Printer reached our work, and from that time to this it has been slowly but steadily progressing. We have completed during the year Vol. VI, *Microscopical Petrography;* Vol. IV, *Paleontology and Ornithology;* and Vol. II, *Descriptive Geology.* The *Geological and Topographical Atlas* has also been finished, the latter consisting of the following sheets: Paper cover, title-page, legend-sheet, sketch-map of the Western Cordilleras, five geological maps, in two sheets each, five topographical maps, in two sheets each, and four sheets of general geological sections.

To complete the report, there will be produced, as already approved, Vol. I, *Systematic Geology,* and Vol. VII, *Vertebrate Paleontology.* The latter volume, together with its illustrations, is now in active preparation at the hands of Professor Marsh, of the Yale museum. Vol. I, my own contribution to the report, is completed, requiring only revision and printing. The illustrations of Vol. I are all done. Judging from the rate of publication of the other volumes, Vol. I will require four months for publication; and if taken up in October, as I hope it will be, the series of reports should be finished early in the following year.

Very respectfully, your obedient servant,

CLARENCE KING,
Geologist in charge.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX N N.

ANNUAL REPORT OF LIEUTENANT GEORGE M. WHEELER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

GEOGRAPHICAL SURVEYS WEST OF THE ONE-HUNDREDTH MERIDIAN IN THE STATES AND TERRITORIES OF CALIFORNIA, OREGON, NEVADA, TEXAS, ARIZONA, COLORADO, IDAHO, MONTANA, NEW MEXICO, UTAH, AND WYOMING.

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REPORT.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL SURVEYS WEST OF THE 100TH MERIDIAN,
Washington, D. C., June 30, 1877.

SIR: I have the honor to submit the following report for the fiscal year ending June 30, 1877:

Including the expeditions of 1876–'77, the fields occupied will have embraced parts of the States and Territories of California, Oregon, Nevada, Texas, Arizona, Colorado, Idaho, Montana, New Mexico, Utah, and Wyoming.

The remaining political divisions of the area west of the one-hundredth meridian, into which parties of this expedition have not entered for its survey, are the State of Kansas and the Territories of Washington and Dakota. The work so far has been directed to the most rugged and thinly-settled portions of the western mountain region. As time and means permit, the areas occupied will adjoin the sections of territory already entered and continue toward completion the topographical survey of the entire region.

SUMMARY OF FIELD AND OFFICE OPERATIONS.

The expedition of 1876, in two sections, (Colorado and California,) took the field during the month of August from Fort Lyon, Col., and Carson, Nev., respectively. Two parties were organized at Fort Lyon and four at Carson.

The expedition of 1877 took the field during the early part of May, resuming the labors as left by parties of 1876 in the Colorado and California sections of the survey, and organizing a third division to operate in portions of Utah, Idaho, and Montana, to be known as the "Utah section" of the survey.

The disbandment of the parties of the 1876 expedition was concluded at Fort Lyon, Col., and Carson, Nev., respectively, during the latter days of November, closing a season of a little less than four months, made short by want of necessary appropriations with which to enter the field during May, as is most economical and satisfactory, and marked by an activity on the part of parties that has afforded favorable results.

The following changes in the *personnel* have occurred during the year:

Lieut. William L. Marshall, Corps of Engineers, relieved from duty August 8, 1876.

Lieut. Samuel E. Tillman, Corps of Engineers, reported for duty August 10, 1876.

Lieut. Thomas W. Symons, Corps of Engineers, reported for duty August 9, in obedience to Special Order No. 161, paragraph 5, Headquarters of the Army, August 8, 1876.

Professor Jules Marcou, a member of the expedition of 1875, and later

connected with the office, called by private business, contributes no longer his valuable labors in western geology, having left the country for Europe for a limited period. Dr. Oscar Loew, whose industry in many fields of scientific inquiry are evidenced by his reports, returns to his home in Germany. His large enthusiasm and commendable energy justifies the hope that he may forego any prolonged professional undertaking there, and return to this country to continue his labors.

The services of Frank Carpenter terminated when he left the United States for the purpose of joining in the surveys now being prosecuted by Americans in Brazil.

Mr. George M. Lockwood, connected with the work since 1873, upon appointment to the chief clerkship of the Paten Office, concluded his service here.

The only appointments made during the year, except as to minor positions, are those of Mr. John A. Church, mining engineer, now engaged in an examination of the mining affairs about the Comstock Lode, and Mr. E. T. Gunter, who accompanies the party of Lieutenant Bergland for the field season. Dr. J. T. Rothrock has been engaged during the year in the completion of his botanical report, which, in connection with the special reports of several scientific gentlemen, will make the body of volume vi.

Prof. F. W. Putnam, without additional compensation, continues his work upon the archæological collections placed in his hands, and brings toward completion the manuscript for volume vii of the quarto reports.

Four general-service clerks have been enlisted, who are called upon, in addition to frequent clerical duty, to assist in the tracing and draughting of maps, and in the field for topographical observations.

I desire to recognize the cheerful assistance frequently extended by the officers of the supply department of the Army in facilitating the progress of the work, and to others, officers of the Government and individuals, who have shown willingness to aid, either directly in the objects sought, or by appreciation of the results obtained.

The following list notes certain of the more prominent features of the field and office work:

FIELD.

Sextant-latitude stations	74
Bases measured	2
Triangles about bases measured	50
Main triangulation-stations occupied	64
Secondary triangulation-stations	80
Station on meanders	5,115
Three-point stations occupied	765
Camps made	317
Miles meandered	4,379.48
Magnetic variations observed	208
Monuments built	168
Cistern-barometer stations occupied	749
Aneroid-stations occupied	3,804
Mining-camps visited	15
Mineral and thermal springs noted	16
Mammals, specimens collected	13
Birds, specimens collected	109
Reptiles, lots collected	10
Fishes, lots collected	9
Insects, lots collected	31
Shells, lots collected	2

OFFICE.

Astronomical positions computed	46
Stations adjusted by method of least squares	93

Triangles computed	279
Distances computed	186
Latitudes and longitudes computed	186
Azimuths computed	186
Sheets and parts of sheets plotted, (1 inch to 2 miles)	17
Special sheets drawn, (various scales)	16
Cistern-barometer altitudes computed	709
Aneroid-barometer altitudes computed	3,709
Atlas-maps (1 inch to 4 miles) published	7
Atlas-maps (1 inch to 4 miles) nearly ready for publication	4
Atlas-maps (1 inch to 4 miles) partially completed	2
Reports published: Volume iv.	
Reports distributed	1,533
Reports in course of publication: Volumes i, vi, vii; Star Catalogue, and table of distances.	
Maps distributed	8,133

ASTRONOMICAL.

The latitudes of a number of points, as determined by the officers of the survey for the season, are herewith given, viz:

Geographical positions, from sextant observations, &c., for the year 1876.

Stations.	Atlas-sheet number.	Objects observed.	Latitude.	Altitude above sea-level.	Variation of needle.	Observer.	Computer.	Remarks.
			° ′ ″	*Feet.*	° ′ ″			
Antoines' Ranch, Nev......	48 D	α Coronæ.....W.; α Pegasi......E.; α Aquilæ......S.; Polaris......N.	39 22 56.5	6,517	17 00 17 E.	Lieu enant Birnie.....	Lieutenant Birnie	On Smi h's Creek.
Anton Chico Road, N. Mex.	77 B	Polaris......N.; α Pegasi......S.; α Aquilæ.....W.	35 04 18.7	6,592	13 46 00	Lieutenant Morrison..	Lieutenant Birnie.....	Near Camp No. 67, party 2, Colorado.
Bench Creek, Nev	48 C	Polaris......N.; ε Pegasi......S.; α Andromedæ. E.; α Lyræ.......W.	39 30 15.2	7,697	16 45 20	Lieutenant Birnie.....	Li.ntenant Birnie	Southwest of Grant Peak.
Birchim's Ranch, Nev	48 D	Polaris......N.; ε Pegasi......S.; α Lyræ.......W.	39 25 28.7	5,743	....	Lieutenant Birnie.....	Li utenant Birnie.....	Reese River Valley.
Buck'and's Ranch, Nev....	48 C	Polaris......N.; ε Pegasi......S.; β Andromedæ E.; α Lyræ ......W.	39 17 48.6	4,151	16 16 37	Lieutenant Birnie....	Lieu'enant Birnie.....	On Carson River.
Cañon del Agua, N. Mex...	77 B	Polaris......N.; α Pegasi......S.; α Arietis......E.; α Aquilæ.....W.	35 19 04.3	5,916	15 16 00	Lieutenant Morrison..	Lieutenant Birnie .; Lieutenant Macomb	Near Mesa Chupaines.
Carson Lake, Nev..........	48 C	Polaris......N.; ε Pegasi......S.; α Andromedæ. E.; α Lyræ ......W.	39 17 11.7	3,883	15 29 42	L'eutenant Birnie	Lieutenant B'rnie	Southwest shore of.
Cerososo Creek, N. Mex ...	70 A	Polaris......N.; α Aquilæ......S.; α Coronæ.....W.	36 44 34.7	7,785	14 30 00	Lieutenant Morrison..	Lieutenant Birnie ...; Lieutenant Macomb	Camp No. 13, party 2, Colorado.
Cleaver's Ranch, Nev......	48 C	Polaris......N.; α Pegasi......S.; α Persei......E.; α Cygni......W.	39 07 18.7	4,337	16 42 44	Lieutenant B'rnie	Lieutenant Birnie.....	On Walker River.
Chalk Well, Nev	48 D	Polaris......N.; α Aquilæ......S.; α Andromedæ E.; α Coronæ.....W.	39 06 35.0	4,604	16 27 03	Lieutenant Birnie	Lieutenant Birnie	On Wadsworth and Lodi Road.

Cherry Valley, Nev	48 C	Polaris......N. ε Pegasi......S. β Andromedæ E. α Lyræ ......W.	39 34 54.7	7,473	15 59 00	Lieutenant Birnie	Lieutenant Birnie	At head of Clan Alpine Creek.
Clover Valley, Cal	47 B	Polaris......N. Sun .... α Aquilæ ......S	39 54 42.0	5,464	16 40 00	Lieutenant Tillman	Lieutenant Birnie	Camp No. 8, party 1, California.
Dead Horse Well, Nev	57 A	Polaris......N. ε Pegasi......S. α Andromedæ E. α Lyræ ......W.	38 53 48.8	4,117	16 30 05	Lieutenant Birnie	Lieutenant Birnie	On Wadsworth and Bellville Road.
Deep Hollow, Nev	48 C	Polaris......N. ε Pegasi......S. β Andromedæ E. α Lyræ ......W.	39 01 29.1	5,244	16 25 04	Lieutenant Birnie	Lieutenant Birnie	On Wadsworth and Bellville Road.
Elliott's Ranch, Cal	47 D	Polaris......N. ε Pegasi......S. α Andromedæ E. α Lyræ ......W.	39 30 14.6	6,233	16 54 53	Lieutenant Tillman	Lieutenant Birnie	Near Little Truckee River.
Ellsworth, Nev	57 B	Polaris ......N. ε Pegasi ......S. α Andromedæ. E. α Lyræ ......W.	38 58 24.2	6,871	....	Lieutenant Birnie	Lieutenant Birnie	Mining town.
Florissant, Colo	62 A	Polaris......N. α Aquilæ ......S.	38 51 34.6	8,184	14 55 08	Lieutenant Bergland	Lieutenant Bergland	South of Camp No. 10, party 1, Colorado.
Florissant, Colo	62 A	Polaris......N. Sun .... α Aquilæ ......S.	38 56 34.7	8,184	14 55 08	Lieutenant Bergland	Lieutenant Bergland	
Gates' Ranch, Nev	48 C	Polaris......N. α Aquilæ ......S. α Pegasi ......E. α Coronæ .....W.	39 22 19.4	4,154	....	Lieutenant Birnie	Lieutenant Birnie	On Carson River.
Glenbrook, Nev	47 D	Polaris......N. Sun............ β Aquarii......S. γ Pegasi ......E. α Coronæ.....W.	39 05 06.2	6,282	15 59 00	Lieutenant Macomb	Lieutenant Macomb	
High Creek, Colo	62 A	Polaris......N. Sun............. α Aquilæ ......S.	38 42 33.3	8,288	15 00 30	Lieutenant Bergland	Lieutenant Bergland	Camp No. 9, party 1, Colorado.
Ione, Nev	57 B	Polaris......N. ε Pegasi......S. α Andromedæ, E. α Lyræ ......W.	38 57 05.1	6,844	15 49 13	Lieutenant Birnie	Lieutenant Birnie	Mining town.
Juan Lujan Spring, N. Mex	77 D	Polaris......N. α Pegasi ......S. α Arietis ......E. α Aquilæ ......W.	34 23 05.1	6,011	13 02 00	Lieutenant Morrison	Lieutenant Birnie	2½ miles south of Camp No. 59, party 2, Colorado.
Lee's Mill, Nev	48 C	Polaris......N. α Pegasi ......S. α Arietis ......E. α Aquilæ .....W.	39 00 50.5	4,350	16 46 15	Lieutenant Birnie	Lieutenant Birnie	Mason Valley.

Geographical positions, from sextant observations, &c., for the year 1876—Continued.

Stations.	Atlas-sheet number.	Objects observed.	Latitude.	Altitude above sea-level.	Variation of needle.	Observer.	Computer.	Remarks.
			° ′ ″	*Feet.*	° ′ ″			
Log Cabin, Nev	48 C	Polaris ......N. ε Pegasi ....S. α Andromedæ E. α Lyræ ....W.	39 26 23.4	4,070	16 49 48	Lieutenant Birnie....	Lieutenant Birnie	On Carson River.
Marlett's Ranch, Nev......	47 D	Polaris ......N. γ Pegasi ......E. α Coronæ.....W. α Lyræ ....W.	39 11 26.7	8,074	16 54 00	Lieutenant Macomb .	Lieutenant Macomb .	
McMahon's Ranch, Nev...	57 B	Polaris ......N. α Pegasi ....S. α Arietis ....E. α Aquilæ .....W.	38 59 33.6	6,552	15 41 17	Lieutenant Birnie.....	Lieutenant Birnie ...	On Reese River.
McLaughlin's Ranch, Colo	53 C	Polaris ......N. Sun............	39 04 35.3	8,226	14 47 30	Lieutenant Bergland..	Lieutenant Berg'and..	
Patterson's Ranch, Nev....	48 D	Polaris .... α Aquilæ .... α Andromedæ ... α Coronæ	39 31 06.1	5,213	16 27 24	Lieutenant Birnie....	Lieutenant Birnie.....	On Edward's Creek.
Ponil Creek, N. Mex	70 A	Polaris ......N. α Aquilæ ......S. α Pegasi........E. α Coronæ .....W.	36 41 42.5	8,333	14 57 00	Lieutenant Morrison	Lieutenant Birnie.... Lieutenant Macomb .	South Fork.
Purgatory River, Colo.....	70 A	Polaris ......N. α Aquilæ ....S. α Coronæ ....W.	37 14 17.9	6,194	14 50 00	Lieutenant Morrison..	Lieutenant Birnie ... Lieutenant Macomb .	Camp No. 8, party 2, Colorado.
Ragtown, Nev	48 C	Polaris ......N. α Aquilæ ......S. α Pegasi ......E. α Coronæ ....W.	39 30 01.7	4,002	17 06 00	Lieutenant Birnie ...	Lieutenant Birnie	On Carson River.
Rendezvous Camp, Nev	47 D	Polaris ......N. α Aquilæ ......S. Sun............ α Pegasi........E. γ Pegasi........E. α Coronæ.....W. α Ophiuchi ...W.	39 10 14.0	4,700	16 46 43	Lieutenant Macomb . Lieutenant Birnie ...	Lieutenant Macomb .. Lieutenant Birnie	Near Carson City, Nev.
Rito Alto, Colo............	61 B	Polaris ......N. Sun............ ε Pegasi ....S.	38 10 46.5	8,169	14 38 00	Lieutenant Bergland..	Lieutenant Bergland..	Foot of.

Rio Grande River, N. Mex..	84 B	Polaris ...... N. α Pegasi .... S. α Arietis ...... E. α Aquilæ ..... W.	33 45 19.1	4,576	13 09 00	Lieutenant Morrison..	Lieutenant Birnie ... Lieutenant Macomb .	Above Fort Craig.
Rosita, Colo	62 C	Polaris ...... N. Sun .... α Pegasi .... S.	38 05 10.7	8,717	14 20 00	Lieutenant Bergland..	Lieutenant Bergland..	
Rowland's, Cal............	56 B	Polaris ...... N. Sun .... α Pegasi .... S. α Persei .... E. α Aquilæ .... W.	38 56 19.4	6,222	15 51 00	Lieut-nant Macomb ..	Lieutenant Macomb ..	
Sierra Valley, Cal.........	47 D	Polaris...... N. Sun............ α Aquilæ ...... S. α Pegasi ...... E. α Coronæ .... W.	39 47 58.1	4,910	16 55 53	Lieutenant Tillman...	Lieutenant Birnie	Camp No. 6, party 1, California.
Sierraville, Cal............	47 D	Polaris ..... N. ε Pegasi ...... S. α Andromedæ . E. α Lyræ .... W.	39 34 58.1	4,904	....	Lieutenant Tillman ..	Lieutenant Birnie	
Silver Age, Nev............	48 D	Polaris ...... N. ε Pegasi .... S. α Andromedæ . E. α Lyræ .... W.	39 24 42.8	6,014	16 31 52	Lieutenant Birnie.....	Lieutenant Birnie	On Big Creek.
Sulphur Spring, Nev	48 C	Polaris ...... N. ε Pegasi .... S. α Andromedæ . E. α Lyræ .... W.	39 17 58.1	3,972	16 55 30	Lieutenant Birnie.....	Lieutenant Birnie	Sand Spring, Alkali Flat.
Tissapok Spring, Nev......	48 C	Polaris ...... N. ε Pegasi .... S. α Andromedæ E. α Lyræ ...... W.	39 08 05.2	5,832	16 43 04	Lieutenant Birnie	Lieutenant Birnie	
Vermejo, N. Mex...........	70 A	Polaris...... N. α Aquilæ ...... S. α Coronæ ..... W.	36 50 58.8	7,823	14 34 00	Lieutenant Morrison..	Lieutenant Birnie ... Lieutenant Macomb	
Washington, Nev	48 D	Polaris...... N. α Pegasi ...... S. α Arietis ...... E. α Aquilæ ..... W.	39 09 34.5	6,992	16 40 24	Lieutenant Birnie	Lieutenant Birnie	
West Gate, Nev............	48 C	Polaris...... N. ε Pegasi .... S. α Andromedæ . E. α Lyræ .... W.	39 17 19.4	4,504	17 03 14	Lieutenant Birnie	Lieutenant Birnie	
Welch's Spring, Nev	57 B	Polaris ...... N. ε Pegasi .... S. α Andromedæ . E. α Lyræ .... W.	38 59 16.1	5,235	16 06 00	Lieutenant Birnie	Lieutenant Birnie	Lodi Valley.

The latitude and longitude and altitude of the main astronomical stations will be given in volume II of the quarto reports, now passing through the press.

It has not been found necessary to occupy further main astronomical stations for the purpose of checking positions determined by other means in the prosecution of work of 1877; but upon the completion of the observatory at Ogden and those contemplated—one at Denver, Col., another on the western slope of the Sierras, a number of points to the north and south of the present line of the Pacific Railroad, *i. e.*, in Oregon, Idaho, Montana, Texas, New Mexico, and Arizona—may be occupied.

GEODETIC AND TOPOGRAPHICAL.

The sketches showing the triangulation in the Colorado, Utah, and California sections are added to as computations progress, and from time to time, as it covers a number of the regular atlas sheets, will be published, as well as the geographical positions, obtained by triangulation, of prominent points. The number of triangulation stations of the highest grade increases each year, and especially in areas where more numerous observations become necessary in order to gather data for delineation on maps of the larger scales. As usual, the areas occupied in the expeditions of 1876 and 1877 follow strictly those authorized by the Chief of Engineers and the honorable the Secretary of War, in pursuance of projects submitted by the officer in charge, and are all laid within that part of the territory of the United States lying west of the one-hundredth meridian, as shown upon the progress map, and over which it is contemplated that topographical surveys in detail commensurate with the character and development of the various sections shall be prosecuted to completion.

The topographical assistants are now required to add to their notes careful data showing the natural resources of the region traversed, in order to collect information as to the general character and value of the areas still belonging to the Government, and it appears that the relative areas of arable, timber, grazing, mineral, and arid lands may be described and delineated.

The noticeable topographical results inaugurated during the year are about Lake Tahoe, in the Sierra Nevada, the topography of which, from data now gathered, warrant a projection on a scale of 1 inch to 1 mile, which has been completed at the hands of a special party engaged upon the high peaks and along the divides of the water courses of this peculiarly interesting lake region.

The plane-table sheets covering the entire Comstock mining district are drawn upon a scale of 1 inch to 500 feet, and will, after reduction, serve as a complete and connected contour map of this region so abundant in the precious metals.

As usual, when practicable, connections have been made with main and minor points of the land survey and monuments built in all cases of due importance. The areas covered by the expedition of 1876 are noted upon the progress map as parts of atlas sheets 47, 48, 56, 61, 62, 70, 77, and 78. Portions of the following basins are embraced, the "Great Interior Basin," and those of the Arkansas and Rio Grande Rivers, as well as the headwaters of a number of streams lining the western slopes of the Sierra Nevada between the latitudinal limits noted on the progress sheet. The gauge of the success of the expedition is better shown by the number and character of the observations made at the main geo-

graphical stations than by the area covered, although the latter is not inconsiderable for so short a season.

A measured and developed base was laid out in the Carson Valley, and connected with the astronomical station established in 1873 at Virginia City, Nev. A description of the apparatus and method employed, by Dr. Kampf, being somewhat typical of that adopted for use upon the survey, is herewith given.

DESCRIPTION OF MEASURING-ROD.

The rod was decided upon by the officer in charge in the winter of 1875–'76, upon consultation with Dr. Kampf, and constructed by Mr. Edward Kahler. It was made of wood, 20 feet in length, strengthened by a vertical cross-piece. Each end of the rod is provided with a scale 8 inches long, subdivided to $\frac{1}{100}$ of an inch, so that by a magnifier it can be read to thousandths. At a point near the center an arc of a circle of 30° extension is fastened. An arm attached to the center of the circle, and movable by a micrometer-screw, carries a level, so that after determining the zero-point on the face of the circle the inclination of the rod can be easily read to 5 minutes. The rod is placed for measurement on two iron-plates, weighing about 30 pounds each, and provided with three strong iron pins 2 inches long. In the center of the plate, on an elevated silver plane, is drawn a cross-line, which acts in the nature of the zero-point of the line.

METHOD OF COMPARISON.

The rod was compared daily, both before and after its use, with two steel standard rods, constructed by the United States Coast Survey, and of a normal length of 5 feet, at the temperature of 61°.6 F. In place of the rod constructed by Mr. Kahler, a similar one, not quite 20 feet long, politely furnished by Mr. Adolf Sutro, of Sutro, Nev., consisting of very well seasoned and varnished wood, was used. A very simple apparatus was used, constructed for comparison, the standard steel rods being supported on two wooden blocks, and therefore elevated by the thickness of this support from the plane of measurement, two knife-blades were driven in a wooden board, 22 by 1½ feet by 4 inches, being as much above the surface of the board as the polished plane at the end of the normal rod. The center of the sharp blade and the plane of the normal rod were brought into the same vertical plane, and by an assistant is kept in this position until the second rod is brought in contact with the first. Thus continuing, the fourth rod was found to reach over the knife-blade about 1½ inches. A square block of wood was placed at the end, in contact with the normal rod, and by means of a small measure, 3 inches long, and divided to hundredths, the distance from the square block of wood to the blade of the knife was read, the temperature being always carefully noted and the measurement repeated.

The readings were made by Dr. Kampf and his assistant. After determining the distance between two points on the edges of the knife-blades, the measuring-rod was placed on top of the blades with the utmost care, and the scale on both ends read. In this manner the amount of over-lapping of the rod was obtained.

Observation made October 11, 1876, between knife-blades, 20 feet 1.537 inches, 55°.8 Fahrenheit; reading of scales on rod, east end, 0.420 inch; west end, 0.140 inch; therefore the length of the rod was determined to be 20 feet + 0.997 inch, at 55°.8 Fahrenheit.

DESCRIPTION OF METHOD OF MEASUREMENT.

Dr. Kampf was aided in the measurement by Mr. Louis Seckels and two laborers. The work was divided among the party as follows: The line was laid out in advance for one day's work, marked by iron pins 2 feet in length and about 180 feet apart. The base was measured on an old road, laid out about ten years ago, and running in a straight line for a distance of $3\frac{3}{4}$ miles. A fine line was tied to one pin and fastened to the next one. Two plates were laid down within the distance of 20 feet 2 inches, approximately, so that they were parallel with the line and tangent to it. One laborer takes the measuring-rod, bringing it near the plates, and the assistant being at the rear end, the laborer on the other, both grasp the rod at the same time and put it on top of the plates $\frac{5}{100}$ of an inch distant from the cross on the ridge of the plates. Mr. Seckels reads the rear end of the scales at the same time that Dr. Kampf reads at the front end by means of a common magnifying-glass. The readings are then at once recorded. After that the level was read by Dr. Kampf and simultaneously with Mr. Seckels, who is now at the front end. He reads the rear end of the scales, and the readings are recorded by both. Then the readings are called out and in case of disagreement repeated. In the meanwhile the other laborer puts an auxiliary rod of 20 feet 2 inches in the position, so that the rear end may be in line with the mark on the plate driving the third plate in the ground. When the readings are finished the new plate is found in its proper position, the laborer brings the rods in front of both plates, and the operation is repeated. The other laborer takes meanwhile the first plate put down and brings it to the front, as No. 4. The thermometer is read from time to time on the shady and sunny side of the rod, to obtain its temperature. After a reasonable practice the rate of measurement may be assumed as 20 feet for each interval of one and one-half minutes.

CO-EFFICIENT OF EXPANSION.

The steel rods of the United States Coast Survey are of normal length at the temperature of 61°.6 F. By means of the co-efficient of expansion for one degrée, as given in Lee's tables, the distance of 20 feet is reduced by applying the temperature of the time of comparison, and thereby the distance between both knife-blades is obtained. To this is added the readings of the scales of the rod, and the length of the rod for the observed temperature is found. The mean of the observations at low and high temperatures are taken, and from the difference of both lengths the factor of expansion is derived, as shown in the next table. The rod having been heavily saturated in a rain and snow storm on October 11, the observations taken afterward are not used for determination of expansion. The length of the rod was found from the comparisons to be $20^{ft}\ 0^{in}.9408$ for 61°.6 F.

Comparisons at low temperature.

Date.		Thermometer reads 61°.6.	Knife-blades distant by reading, 20 feet.	Corrections for expansion of 20-foot steel rod.	Actual distance of knife-blades, 20 feet.	Sum of readings of wooden rod.	Wooden rod equal to 20 feet.
1876.		°	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
September	23	−14.1	−1.4950	−0.0215	−1.5165	0.4950	−1.0215
	24	− 6.6	−1.4950	−0.0101	−1.5051	0.4940	−1.0111
	25	−10.3	−1.4960	−0.0157	−1.5117	0.4980	−1.0137
	26	− 7.6	−1.5150	−0.0116	−1.5266	0.5050	−1.0216
	27	−10.6	−1.5000	−0.0162	−1.5162	0.5070	−1.0092
	28	− 3.1	−1.5150	−0.0047	−1.5197	0.5170	−1.0027
	29	− 8.8	−1.5100	−0.0134	−1.5234	0.5270	−0.9964
	30	− 6.6	−1.5230	−0.0101	−1.5331	0.5320	−1.0011
October	1	− 7.8	−1.5260	−0.0119	−1.5379	0.5390	−1.0079
	2	− 2.4	−1.5340	−0.0037	−1.5377	0.5390	−0.9987
	3	− 9.6	−1.5180	−0.0146	−1.5326	0.5350	−0.9976
	4	− 9.6	−1.5350	−0.0146	−1.5496	0.5410	−1.0086
	5	− 9.6	−1.5330	−0.0146	−1.5476	0.5390	−1.0086
	6	−10.2	−1.5330	−0.0156	−1.5486	0.5410	−1.0076
	7	− 5.6	−1.5440	−0.0085	−1.5525	0.5410	−1.0115
	8	+ 0.4	−1.5580	+0.0006	−1.5574	0.5490	−1.0784
	10	−13.0	−1.5450	−0.0198	−1.5648	0.5590	−1.0058
	11	− 5.8	−1.5370	−0.0088	−1.5458	0.5600	−0.9858
	11	− 2.6	−1.5370	−0.0040	−1.5410	0.5410	−1.0000

Mean length of rod at 54° 5 F. = 20 feet — 1 0062 inch.

Comparisons at high temperature.

Date.		Thermometer reads 61°.6.	Knife-blades distant by reading, 20 feet.	Correction for expansion of 20-foot steel rod.	Actual distance of knife-blades, 20 feet.	Sum of readings of wooden rod.	Wooden rod equal to 20 feet.
1876.		°	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
September	23	+51.4	−1.5500	+0.0784	−1.4716	0.5110	−0.9606
	24	+36.4	−1.5450	+0.0555	−1.4895	0.5050	−0.9845
	25	+39.4	−1.5540	+0.0601	−1.4939	0.5200	−0.9739
	26	+48.4	−1.5320	+0.0739	−1.4581	0.5180	−0.9401
	27	+23.4	−1.5350	+0.0357	−1.4993	0.5220	−0.9773
	28	+11.4	−1.5480	+0.0220	−1.5260	0.5280	−0.9980
	29	+22.0	−1.5390	+0.0336	−1.5054	0.5320	−0.9734
	30	+47.9	−1.5650	+0.0731	−1.4910	0.5390	−0.9529
October	1	+11.4	−1.5410	+0.0174	−1.5236	0.5410	−0.9826
	2	+60.4	−1.5640	+0.0922	−1.4718	0.5540	−0.9178
	3	+44.4	−1.5750	+0.0677	−1.5073	0.5420	−0.9653
	4	+52.4	−1.5750	+0.0800	−1.4950	0.5450	−0.9500
	5	+60.4	−1.5880	+0.0922	−1.4958	0.5510	−0.9448
	6	+56.4	−1.5740	+0.0861	−1.4879	0.5960	−0.9419
	7	+18.4	−1.5730	+0.0281	−1.5449	0.5420	−1.0029
	8	+17.4	−1.5740	+0.0266	−1.5476	0.5510	−0.9966
	10	+33.4	−1.5750	+0.0509	−1.5241	0.5620	−0.9621

Mean length of rod at 99°.0 F. = 20 feet — 0.96616 inch.

Expansion of rod for 44°.5 F. = 0.04004 inch.
Expansion of rod for 1°.0 F. = 0.00090 inch.

REDUCTION OF OBSERVATIONS.

The following corrections are applied to the number of rods multiplied by 20 feet:

(1) Difference of rod from 20 feet at mean temperature of all observations multiplied by the number of rods measured.

(2) Readings of both ends of wooden rod when lying on the plates.

(3) Correction for inclination.

The following table contains the corrections for (1):

First measurement.

Date.	Mean temperature.	Number of rods measured.	Equivalent number of rods of 20 feet.
			Inches.
September 23	88	104	−101.5467
24	80	104	−102.1987
25	89	54	− 52.6305
26	86	109	−106.5279
27	65	102	−101.6022
28	81	104	−102.1061
29	89	111	−108.2337
30	84	105	−102.9000
October 1	92	98	− 95.3392
2	94	108	−104.8724
3	93	110	−106.8146
4	85	72	− 70.4312

First measurement, 1,181 rods − 1,155.2558 inches.

Second measurement.

Date.	Mean temperature.	Number of rods measured.	Equivalent number of rods of 20 feet.
			Inches.
October 5	92	144	144.8357
6	97	151	146.1710
7	92.5	152	147.7516
8	83	150	151.9837
10	88	145	141.5302
11	58	129	128.3945
17	63	148	139.4297
18	57	150	141.7125

Second measurement, 1,179 rods − 1,142.4090 inches.

DEDUCTION OF RESULTS OF LENGTHS OF BASE NEAR SUTRO, NEV.

	First measurement.	Second measurement.
Sum of corrections for (1)	— 96.2713	— 95.2007
Sum of corrections for (2)	—101.2506	— 62.2997
Sum of corrections for (3)	— 1.1624	— 1.1492
Sum of corrections	—198.6843	—158.6496
Number of rods multiplied by 20 feet	23620.0000	23580.0000
Length of base	23421.3157	23421.3504
Mean		23421.333
Reduction to level of the sea		— 4.946
Resulting length, (feet)		23416.387

ROUTES OF COMMUNICATION.

A small number of tables of distances taken from the road-measurements of 1876 are herewith given.

In each subsequent annual report the routes joining the main terminal points of lines of present or prospective importance will be given, and the consolidated table mentioned in my last annual report will soon be made more complete and forwarded for publication.

During the year a number of distances between military posts, principally in the departments of the Missouri and Arizona, have been furnished to the Paymaster-General, United States Army.

LIST OF ROAD-DISTANCES BETWEEN PROMINENT POINTS MEANDERED BY PARTY NO. 1, COLORADO SECTION, 1876.

La Junta to Pueblo.
Pueblo to Cañon and Florissant.
Florissant to Fair Play.
Fair Play to South Arkansas Post Office.
South Arkansas Post Office to Mosca Creek Forks.
Mosca Creek to Rosita.
Rosita to Cañon City.
Cañon City to Colorado Springs.

From La Junta, Colo., to Pueblo Post Office, Colo.—Atlas-sheet No. 62.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From La Junta.	From Pueblo.		
La Junta, Colo		....	65.05	4,094	No wood or grass near town.
Texas Bend	4.78	4.78	60.27	4,169	
Rocky Ford	6.76	11.54	53.51	....	
Apishpa Creek	13.49	25.03	40.02	4,266	
Huerfano River	19.19	44.22	20.83	4,324	
Old Fort Reynolds	2.60	46.82	18.23	....	
Fork of road to Pueblo and South Pueblo.	12.27	59.09	5.96	....	
South Pueblo, lower bridge	5.36	64.45	0.60	4,584	
Pueblo Post Office	0.60	65.05	....	....	

Road along south bank of Arkansas River.

From Pueblo, Colo., to Cañon and Florissant.—Atlas-sheet No. 62.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Pueblo.	From Cañon City and Florissant.		
Pueblo Post-Office		....	90.65	4,584	Grass and fuel along river bottom.
Big Turkey Creek	12.64	12.64	78.01	4,947	
Beaver Creek	8.26	20.90	69.75	5,148	
Ute Creek	10.17	31.07	59.58	....	
Eight-mile Creek	1.46	32.53	58.12	....	
Oil Creek	3.75	36.28	54,37	5,241	
Cañon City Post Office	3.05	39.33	51.32	5,325	
Forks of road, (Pleasant Valley)	8.25	47.58	43.07	6,271	
Currant Creek, (12-mile ranch)	3.90	51.48	39.17	6,019	
Eighteen-mile Ranch, forks of road to Fair Play.	5.57	57.05	33.60	7,161	
South Fork Wilson Creek	5.13	62.18	28.47	7,401	
Divide between Wilson and High Creek.	3.10	65.28	25.37	8,439	
Crossing High Creek	3.80	69.08	21.57	8,401	Good grass, fuel, and water.
Settlement on west fork Oil Creek	3.84	72.92	17.73	8,259	Valley fenced in.
Down west fork to near mouth	4.50	77.42	13.23	7,924	Do.
Up Oil Creek to Summit, Twin Creek Pass.	8.73	86.15	4.50	8,790	Good grass and water.
Florissant Post Office	4.50	90.65	....	8,184	Good grass, water, and fuel.

From Florissant, Colo., to Fair Play, Colo., via Tarryall Creek.—Atlas-sheet Nos. 62, 53, and 52.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Florissant.	From Fair Play.		
Florissant Post-Office		....	60.80	8,184	
South Platte Bridge	4.97	4.97	55.83	7,978	
McLaughlin's ranch	7.47	12.44	48.36	8,226	Camp. Grass, wood, and water.
Duck Lake	15.23	27.67	33.13	8,807	Do.
Fork of road to Fair Play	7.90	35.57	25.21	9,035	
Up Rock Creek to the point where the road leaves the creek.	3.67	39.24	21.56	9,239	
Confluence Michigan and Jefferson Creek.	4.90	44.14	16.66	9,298	No wood near road.
Tarryall River bridge below Hamilton, (by the shortest trail.)	5.16	49.30	11.50	9,713	No wood near road.
Summit road	7.26	56.56	4.24	9,958	No wood near road.
Fair Play Post Office	4.24	60.80	....	9,929	Wood scarce, grass medium, water good. Hay and grain for sale in town.

The above road is not the shortest road between Florissant and Fair Play. The stage-road leaves it near the South Platte bridge.

From Fair Play, Colo., to South Arkansas Post Office.—Atlas-sheet Nos. 52 *and* 61.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Fair Play.	From South Arkansas Post Office.		
Fair Play Post Office		....	59. 07	9, 928	
Four-mile Creek	3. 77	3. 77	55. 30	9, 670	
Ranch on Dry Creek	5. 55	9. 32	49. 75	9, 317	
South Fork South Platte River	2. 65	11. 97	47. 10	9, 161	
Buffalo Springs	4. 41	16. 38	42. 69	8, 952	
Salt-Works	4. 16	20. 54	38. 53	8, 969	Camp. Grass and water, but no wood. Hill moderate.
Divide between Platte and Arkansas Rivers.	3. 47	24. 01	35. 06	9, 464	
Riverside Post Office	2. 14	26. 15	32. 92	9, 144	
Springs, Trout Creek	2. 18	28. 33	30. 74	8, 963	
Fork of roads up and down Arkansas River.	8. 18	36. 51	22. 56	7, 937	
Arkansas Bridge	3. 15	39. 66	19. 41	7, 741	Good bridge.
Chalk Creek	2. 16	41. 82	17. 25	7, 729	
Centreville Post Office	2. 38	44. 20	14. 87	7, 690	
Brown's Creek	1. 40	45. 60	13. 47	7, 828	Grass and wood scarce.
Three-mile Creek	2. 29	47. 89	11. 18	7, 926	
Squan Creek	5. 70	53. 59	5. 48	7, 279	
South Arkansas Post Office	5. 48	59. 07	....	7, 383	Wood and water good. Poor grass.

From South Arkansas Post Office to Mosca Creek, fork of roads.—Atlas-sheet No. 61.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From South Arkansas post-office.	From Mosca Creek.		
South Arkansas Post-Office		....	65. 11	7, 383	
Toll-gate	3. 42	3. 42	61. 69	8, 216	Puncho Pass.
Summit Puncho Pass	4. 63	8. 05	57. 06	8, 945	
Round Mountain Ranch PostOffice	2. 67	10. 72	54. 39	8, 732	
Hall's, Kerber Creek	11. 81	22. 53	42. 58	7, 900	
Bismarck Post Office	8. 10	30. 63	34. 48	7, 736	
Major Creek	2. 46	33. 09	32. 02	7, 686	
Wild Cherry Creek	3. 24	36. 33	28. 78	7, 431	Grass poor and wood scarce near road; better grass and wood in abundance found in the foot-hills of Sangre de Cristo Range.
Rito Alto Post Office	2. 08	38. 41	26. 70	7, 484	
San Irabel Post Office	3. 74	42. 15	22. 96	7, 537	
Crestones Creek	3. 12	45. 27	19. 84	7, 517	
Willow Creek	2. 75	48. 02	17. 09	....	
Cottonwood Creek	2. 00	50. 02	15. 09	7, 566	
Deadman Creek	2. 30	52. 32	12. 79	....	
Sandhill Creek, (old Star ranch)	9. 60	61. 92	3. 19	7, 587	
Spring Creek	1. 55	63. 47	1. 64	7, 560	Road very sandy.
Mosca Creek	1. 64	65. 11	....	7, 549	

Road through Puncho Pass is kept in good condition.

From Mosca Creek to Rosita, Colo.—Atlas-sheets No. 61 *and* 62.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Mosca Creek.	From Rosita.		
Mosca Creek, fork of roads	7.73	....	43.01	7,549	
Ranch, western entrance to Mosca Pass.	3.22	7.73	35.28	8,172	Camp. Grass poor; wood and water good.
Summit Mosca Pass	5.13	10.95	32.06	9,787	Road good through pass.
Fork of roads to Gardner's	6.90	16.08	26.93	8,805	
Intersection, creek and cross-road	2.52	22.98	20.03	7,977	
Muddy River, forks of road	4.43	25.50	17.51	7,916	
Divide between Arkansas and Huerfano Rivers.	4.82	29.93	13.08	8,428	
Forks of road to Colfax	2.64	34.75	8.26	8,223	
Forks, U-la road	2.76	37.39	5.62	8,174	
Rosita and U-la road	2.86	40.15	2.86	8,327	
Rosita		43.01	....	8,717	Good wood, grass, and water near town; hay and grain for sale.

This is the old road from Mosca Pass to Rosita, and is now practicable only for lightly-loaded wagons

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From Rosita, Colo., to Cañon City, Colo.—Atlas-sheet No. 62.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Rosita.	From Cañon City.		
Rosita	13.56	....	30.76	8,717	
Oak Creek, (blacksmith-shop)	2.51	13.56	17.20	7,987	
Yorkville	5.11	16.07	14.69	7,727	Post Office.
Point where road leaves Oak Creek	0.91	21.18	9.58	6,105	
Summit road	0.44	22.09	8.67	6,829	
Forks of road, Cañon City and Labran	3.27	22.53	8.23	6,678	
Crossing Milk Creek	4.45	25.80	4.96	5,939	
Arkansas River bridge	0.51	30.25	0.51	5,302	
Cañon City Post Office		30.76	....	5,323	

This is the stage-road between Cañon City and Rosita. Grades are easy and road in good condition.

From Cañon City, Colo., to Colorado Springs.—Atlas-sheet No. 62.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Cañon City.	From Colorado Springs.		
Cañon City Post Office		....	45.39	5,325	Corrals in town; no wood or grass near town.
Railroad-crossing	2.24	2.24	43.15	....	
Oil Creek	0.81	3.05	42.34	5,241	No bridge.
Eight-mile Creek	4.48	7.53	37.86	5,540	
Ute Creek	2.14	9.67	35.72	....	
Beaver Creek Crossing	6.61	16.28	29.11	5,930	Camp. Grass scarce; wood and water in abundance.
Fork Big Turkey Creek	9.33	25.61	19.78	6,480	
Big Turkey Creek	2.50	28.11	17.28	6,519	
West Fork Little Fountain Creek	2.61	30.72	14.67	6,180	
Confluence, east and west forks	1.13	31.85	13.54	6,109	
Bend of road	2.21	34.06	11.33	6,000	
Railroad-crossing	10.39	44.45	0.94	5,875	
Colorado Springs, center of town	0.94	45.39	....	5,946	Animals in corrals; grain and feed purchased.

This is not the usually-traveled road between Cañon City and Colorado Springs; it is called the "short cut," but is impracticable for heavily-loaded wagons between Beaver Creek Crossing and Big Turkey Creek.

LIST OF ROAD-DISTANCES BETWEEN PROMINENT POINTS, MEANDERED BY PARTY NO. 2 COLORADO SECTION, 1876.

Trinidad to Santa Fé.
Fort Lyon to Trinidad.
Santa Fé to Tejique.
Socorro to Las Lunas.
Valencia to Socorro.
Socorro to Fort Craig.
Socorro to Guinisa.
Ojo de las Casas to Las Lunas.
Pedernal to Manzano.
Tejique to Pedernal.
Pedernal to Anton Chico.
Antelope Spring to Los Pesos.
Tangues de Juan Lojair to Cienega de Tula.
Anton Chico to Fort Lyon.

From Trinidad, Colo., to Santa Fé, N. Mex., via Long's Cañon and Taos Pass.—Atlas-sheets 70A, 70C, and 69D.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Trinidad.	From Santa Fé.		
Trinidad		....	188.46	....	Town; Government agency.
Junctions Long's Creek and Purgatory	6.54	6.54	181.92	....	Ranches.
Long's Cañon Pass	21.51	28.05	160.41	8,402	Good grazing; water in spring below summit.
Vermejo Creek, Cameron's	18.34	46.39	142.07	7,133	Ranches.
Van Brummer Park	13.66	60.05	128.41	8,557	Lakes; fair grazing.
Ponil Creek	6.00	66.05	122.41	....	Good grazing.
South Fork Ponil Creek	7.05	73.10	115.36	8,332	Poor grazing.
Ponil Pass	6.99	80.09	108.37	9,848	Good grazing.
Elizabethtown	4.33	84.42	104.04	....	Mining town.
Six-mile Creek	7.25	91.67	96.79	8,450	Good grazing; ranches.
Kennedy's Ranch	7.71	99.38	89.08	....	Deserted; wood, water, grass.
Taos Pass	2.06	101.44	87.02	9,282	Wood, water, grass, below summit.
Mouth of Fernandez Creek	14.43	115.87	72.59	....	Poor grazing.
Ranchos de Taos	4.07	119.94	68.52	....	Mexican town; forage.
Junction with Government road	5.34	125.28	63.18	....	
Cineguilla	8.28	133.56	54.90	6,011	Mexican town; wood and water.
Plaza del Alcalde	23.30	156.86	31.60	5,756	Government agency: Mexican town.
Pueblo de San Juan	2.94	159.80	28.66	5,870	Government agency.
Santa Cruz	4.22	164.02	24.44	....	Do.
Pojoaque	7.27	171.29	17.17	....	Do.
Cuyamunque	27.24	174.01	14.45	....	Mexican town.
Tesuque	5.096	179.11	9.35	....	Indian pueblo.
Santa Fé	9.348	188.46	....	....	Military post; large town.

The road is practicable for wagons. Descending to Vermejo Creek there is a steep hill for half a mile.

From Fort Lyon, Colo., to Trinidad, Colo.—Atlas-sheets Nos. 62CD and 70A.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Fort Lyon.	From West Las Animas.		
Fort Lyon		....	....	3,938	Government post.
Purgatory River	3.414	....	....	....	Poor grazing.
West Las Animas	2.090	5.494	....	4,040	Town; railroad.
Sizer's Ranch	6.447	11.941	......	4,040	Government agency.
Alkalis Station	11.981	23.922	18.428	4,136	Deserted; poor water; little wood.
Vogel's Cañon	10.230	34.152	28.658	4,205	Deserted; poor water; poor grazing.
Bent's Cañon	15.613	49.765	44.271	4,696	Do.
Lockwood's Ranch	13.482	63.247	57.753	4,997	Do.
Hogback	16.773	80.020	74.526	5,423	No wood; little water and grass.
Chicoso Creek	14.619	94.639	89.145	5,840	Ranches; grazing generally eaten up.
El Moro	10.246	104.885	99.391	....	Denver and Rio Grande Railroad.
Trinidad, Colo.	5.145	110.030	104.536	......	Town; forage; Government agency.

Country generally worthless. River-bottom cultivated; water elsewhere scarce and alkaline. Bluffs wooded with piñon and cedar. Grazing good, but usually closely eaten.

From Santa Fé, N. Mex., to Tijeras, N. Mex.—Atlas-sheet No. 77 B and D.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Santa Fé.	From Tijeras.		
Santa Fé, N. Mex		....	57.35	....	Town; Government post.
Forks of road	9.590	....	47.75	....	
San Marcos Spring	8.951	18.541	38.80	6,036	Good water; little wood; good grass.
Galisteo Creek	3.003	21,544	35.80	....	Good water; wood plenty; good grass.
Old Placer	6.193	27.739	29.60	....	Mining town; little of anything.
Fork roads	6.339	34.078	23.27	....	Good grazing and wood; no water.
New Placer	2.906	36.984	20.36	6,667	Mining town; wood and water.
Fork roads	1.553	38.537	18.81	....	Good grazing.
San Pedro	7.384	45.921	11.43	....	Deserted.
San Antonito	3.759	49.680	7.67	....	Mexican town.
Cañoncito	3.028	52.708	4.64	....	Do.
San Antonio	2.541	55.249	2.10	....	Do.
Tijeras	2.105	57.354	....	....	Do.

Grazing in general, good; wood, cedar and piñon, abundant; water, scarce.

From Socorro, N. Mex., northwest bank Rio Grande, to Las Lunas.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Socorro.	From Las Lunas.		
Socorro		....	56.88	4,659	Mexican town, Government agency.
Escondida	4.96	4.96	51.92	....	Mexican town.
Limitar	4.23	9.19	47 69	....	Do.
Palvadera	2.25	11.44	45.44	....	Do.
Alamillo	3.42	14.86	42.02	4,693	Mexican town, Government agency.
San Geronimo	7.27	22.13	34.75	....	Mexican town.
San Carlos	1.61	23.74	33.14	....	Do.
Rio Puerco	2.42	26.16	30.72	....	Water.
Sabinal Agency	3.83	29.99	26.89	4,757	Mexican town, Government agency.
Pueblito	2.14	32.13	24.75	....	Mexican town.
Sabinal	1.07	33.20	23.68	....	Do.
Ranchitos	2.32	35.52	21.36	....	Do.
Bosque	3.05	38.57	18.31	....	Do.
Pueblitos de Belen	3.50	42.07	14.81	....	Mexican town, Government agency.
Belen	3.69	45.76	11.12	4,890	Do.
Ranchitos de Belen	1.71	47.47	9.41	....	Mexican town.
Los Charez	3.65	51.12	5.76	....	Do.
Las Lunas	5.76	56.88	....	4,921	Mexican town, Government agency.

From Valencia, N. Mex., northeast bank Rio Grande, to Socorro, N. Mex.—Atlas-sheet No. 77 D.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Valencia.	From Socorro.		
Valencia		....	60. 78	....	Mexican town.
Tome	5. 28	....	45. 50	....	Do.
Ranchitos de Tome	1. 15	6. 43	54. 35	....	Do.
Constancia	3. 57	10. 00	50. 78	....	Do.
Casa Colorado	8. 26	18. 26	42. 52	....	Do.
Vellita	4. 80	23. 06	37. 72	....	Do.
Chihuahua	1. 81	24. 87	35. 91	....	Do.
Las Nuetrias	1. 15	26. 02	34. 76	....	Do.
Ranchos	7. 12	33. 14	27. 64	....	Do.
La Joya	3. 15	36. 29	24. 49	....	Do.
La Joyita	6. 54	42. 83	17. 95	....	Do.
Sabina	7. 05	49. 88	10. 90	....	Deserted.
Pueblito de la Parida	4. 99	54. 87	5. 91	....	Ranch.
La Parida	1. 70	56. 57	4. 21	....	Town, Mexican.
Socorro	4. 21	60. 78	....	4, 659	Town.

Rio Grande Valley: arable; generally entirely taken up with ranches. No Government agencies on east bank.

From Socorro, N. Mex., to Fort Craig.—Atlas-sheets Nos. 77 D and 84 A.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Socorro.	From Fort Craig.		
Socorro		....	64. 64	4, 659	Mexican town, Government agency.
San José	5. 562	....	59. 08	....	Do.
San Antonio	5. 937	11. 499	53. 14	....	Do.
San Marcial	19. 742	31. 241	33. 40	....	Do.
From Fort Craig to Bosquecito.					
Fort Craig	4. 098	35. 339	29. 30	4, 619	Government post.
Contradero	1. 000	36. 339	28. 30	....	Mexican town.
La Mesa	4. 295	40. 634	24. 01	....	Do.
Valverde	2. 360	42. 994	21. 65	....	Do.
Bosquecito	21. 651	64. 645	....	....	Do.

No wood near the river. Grazing fair. Little inhabited.

From Socorro, N. Mex., to Ojo de la Quinsa.—Atlas-sheets Nos. 77D and 77C.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Socorro.	From Ojo de la Quinsa.		
Socorro		....	38.88	4,659	Mexican town.
Ojo de la Culebra	11.198	....	27.68	5,707	Spring, ranch, wood, water, and grass.
Cañon del Agua	8.480	19.678	19.20	6,833	Wood, water, and grass abundant.
Junction road from Socorro	6.559	26.237	12.64	....	Partially over; no marked trail.
Junction road from Socorro	3.309	29.54	9.33	....	
Main fork roads	1.834	31.38	7.49	....	
Ojo de la Quinsa	7.494	38.88	....	5,673	Ranch, spring, no wood, poor grazing.

From Ojo de las Casas, N. Mex., to Las Lunas.—Atlas-sheet No. 77D.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Ojo de las Casas.	From Las Lunas.		
Rio de la Casa		....	21.47	6,243	Spring; wood, and fine grazing.
Ojuelos	5.610	....	15.86	....	Ranch; no wood; grazing.
Junction road to Cañon Ojito	4.864	10.474	11.00	....	
Crossing road from Hell Cañon	.927	11.401	10.07	....	To Las Lunas.
Crossing road from Hell Cañon	2.369	13.770	7.69	....	
Peralta	3.626	17.396	4.07	....	Mexican town.
Valencia	2.082	19.478	1.99	....	Do.
Las Lunas	1.986	21.464	....	4,921	Mexican town, Government agency.

From Pedernal Water-hole to Manzano, New Mex.—Atlas-sheet No. 77D.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Pedernal Water-hole.	From Manzano.		
Pedernal Water-hole		....	64.66	7,140	Spring in spur of peak to south.
Junction road to Estancia	1.000	....	63.66	....	
Fork road to Los Posos	7.806	8.806	55.85	....	
Los Cañoncitos	12.098	20.904	43.75	....	Water-holes, permanent.
Junction road from Los Posos	1.775	22.679	41.98	....	
Fork to Mesteñito	1.349	24.028	40.63	....	
Laguna de Sol	4.644	28.674	35.99	6,041	Salt lake.
Fork of roads	4.989	33.663	31.00	....	
Junction road from Pedernal	5.426	39.089	25.57	....	
Ojo de Estañcia	3.343	42.432	22.23	6,177	Ranch; forage and grazing good.
Junction road to Mesteñito	3.126	45.558	19.10	....	
Crossing road to Manzano	11.862	57.420	7.24	....	
Punta del Agua	2.173	59.593	5.07	....	Mexican town.
Manzano	5.071	64.664	....	....	Do.

From Tejique, N. Mex., to Pedernal Water-hole.—Atlas-sheet No. 77D.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Tijique.	From Pedernal Water-hole.		
Tejique	17.794	....	43.62	....	Mexican town.
Ojo de Estancia	4.550	....	25.83	6,177	Ranch spring.
Cross-road from Antelope Spring	6.857	22.344	21.28	....	
Road from Antelope Spring	13.419	29.201	14.42	....	
Junction road from Los Posos	1.000	42.620	1.00	....	
Pedernal Water-hole		43.620	....	7,140	Spring on south spur from peak.

From Pedernal Water-hole to Anton Chico.—Atlas-sheet No. 69D and 78A.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Pedernal Water-hole.	From Anton Chico.		
Pedernal Water-hole	11.78	....	48.90	7,140	Spring on south spur from peak.
Albuquerque road	6.74	....	37.12	....	
Las Tanques Empedrador	11.73	18.52	30.38	....	Water-holes, not permanent.
Cañon Blanco	18.65	30.25	18.65	....	Water-holes.
Anton Chico		48.90	....	....	Mexican town.

Grazing excellent everywhere; wood occurs on highest points, but usually at some distance from water. Beyond Pedernal, wood and grass abundant.

From Antelope Spring to Los Posos del Pino.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Antelope Spring.	From Los Posos del Pino.		
Antelope Spring	8.05	....	42.16	6,221	Ranch, Government agency.
Cross-road from Estancia	7.85	....	34.11	....	
Laguna de Sal	9.93	15.85	26.31	6,041	
Tanques de las Caminos	9.25	25.78	16.38	....	Water-holes, not permanent.
Junction main road to Stanton	7.13	35.03	7.13	....	
Los Posos del Pino		42.16	....	6,168	Ranch, Government agency.

From Tanques de Juan Lujan to Cienega de Tula.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Tanques de Juan Lujan.	From Cienega de Tula.		
Tanques de Juan Lujan	7.55	....	37.41	....	
Abo Pueblo	12.93	....	29.86	....	
Pueblo de Quará	0.92	20.48	16.93	....	
Punta de Aqua	11.55	21.40	16.01	....	
Mesteñito	4.46	32.95	4.46	6,268	
Cienega de Tula		37.41	....	....	

From La Liendre, N. Mex., to Fort Lyon, Colo.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From La Liendre.	From Fort Lyon.		
La Liendre Church	7.37	....	154.92	....	Mexican town
Head Cañon del Agua	2.34	7.37	147.55	6,353	Water-holes and springs; deserted houses.
Camp 71	9.90	9.71	145.21	6,736	Water-holes.
Las Vegas	11.30	19.61	135.31	....	Town; Government agency.
Los Alamos	18.86	30.91	124.01	6,789	Town, Mexican; forage.
Fort Union	5.61	49.77	105.15	6,715	Post.
Collier's Ranch	6.61	55.38	99.54	....	Spring, private.
Las Gallinas	10.74	61.99	92.93	....	Mexican town.
Apache Spring	9.62	72.73	82.19	....	No wood.
Ocate Creek	11.67	82.35	72.57	....	Do.
Rock Ranch	20.81	94.02	60.90	5,844	Government agency.
Chico Spring	13.00	114.83	40.09	6,882	Do.
Kiowa Spring, Taylor's Ranch	4.25	127.83	27.09	7,226	Spring; no wood.
Camp 77 (ponds)	11.91	132.08	22.84	7,036	Water slightly brackish.
Pinavete Spring	6.24	143.99	10.93	....	Wood abundant.
Walter's Ranch	4.69	150.23	4.69	....	Head Dry Cimarron Cañon.
Emery's		154.92	....	6,080	Government agency; Dry Cimarron.

From Anton Chico to Fort Lyon, Colo.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Anton Chico.	From Fort Lyon.		
Emery's Ranch	2.45	....	103.27	6,080	Government agency.
Toll-gate, Metcalf's	5.38	2.45	100.82	......	
Boundary (nearly)	9.35	7.83	95.44	....	
Chaquaquo Cañon	12.65	17.18	86.09	5,932	Water-holes; grazing; little wood.
Fork roads	2.56	29.83	73.44	....	
Pinavete Spring	9.08	32.39	70.88	....	Wood, water, and grass.
Camp head Plum Cañon	4.33	41.47	62.80	5,754	Water-holes; wood; grazing.
Head Smith's Cañon	20.27	45.88	58.47	....	Water.
Camp Smith's Cañon	8.90	66.09	38.20	4,523	Water; little grass and wood.
Purgatoire Ranch, Nine-mile Bottom	7.92	74.99	29.30	....	Ranches.
Alkali Cañon	11.70	82.89	21.38	....	Stage station, deserted.
Sizer's Ranch	9.68	94.59	9.68	4,035	Government agency.
Fort Lyon		104.27	....	3,938	Post.

LIST OF ROAD-DISTANCES BETWEEN PROMINENT POINTS, MEANDERED BY PARTY NO. 1, CALIFORNIA SECTION, 1876.

Carson to Reno.
Reno to Beckwith's Store.
Reno to Milford.
Reno to Truckee.
Reno to Milton.
Truckee to Sierraville.

From Carson, Nev., to Reno, Nev.—Atlas-sheet No. 47d.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Carson.	From Reno.		
Carson	10.080	0.000	31.965	....	State-house.
Franktown	4.971	10.080	21.885	....	Railroad station.
Washoe City	5.501	15.051	16.814	....	Do.
Steamboat Springs	4.706	20.552	11.413	....	Do.
Hoffakers	6.707	25.258	6.707	....	Do.
Reno		31.965	0.000	....	Crossing C. P. R. R.

From Reno, Nev., to Beckwith's Store, Cal.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Reno.	From Beckwith's Store.		
Reno	10.741	0.000	42.621	....	
Peavine Ranch	14.048	10.741	31.880	....	
Junction House	3.610	24.789	17.832	....	
Summit	14.222	28.399	14.222	....	Post-Office, Sierra Valley.
Beckwith's Store		42.621	0.000	....	Do.

From Reno, Nev., to Milford, Cal.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Reno.	From Milford.		
Reno	24.789	0.000	64.225	....	
Junction House	21.619	24.789	39.436	....	
Willow Ranch	17.817	46.408	17.817	....	
Milford		64.225	0.000	....	

From Reno, Nev., to Truckee, Cal.—Atlas-sheet No. 47 d.

	Distance in miles. Between consecutive points.	Distance in miles. From Reno.	Distance in miles. From Truckee.	Altitude in feet above sea-level.	Remarks.
Reno		0.000	31.665	....	
Crystal Peak	12.705	12.705	18.960	....	Village.
Forks of Henness Pass Road	5.850	18.555	13.110	....	
Virginia House	4.580	23.135	8.530	....	Stage station.
Prosser Creek	4.474	27.609	4.056	....	
Truckee	4.056	31.665	0.000	....	

From Reno, Nev., to Milton, Cal.

	Distance in miles. Between consecutive points.	Distance in miles. From Reno.	Distance in miles. From Milton.	Altitude in feet above sea-level.	Remarks.
Reno		0.000	49.006	....	
Forks of Henness Pass Road	18.555	18.555	30.451	....	
Webber Lake	18.626	37.181	11.825	....	
Milton	11.825	49.006	0.000	....	

From Truckee, Cal., to Sierraville, Cal.

	Distance in miles. Between consecutive points.	Distance in miles. From Truckee.	Distance in miles. From Sierraville.	Altitude in feet above sea-level.	Remarks.
Truckee		0.000	26.140	....	
Prosser Creek	4.056	4.056	22.084	....	
Cory's Ranch	11.413	15.469	10.671	....	
Sierraville	10.671	26.140	0.000	....	

LIST OF ROAD-DISTANCES BETWEEN PROMINENT POINTS, MEANDERED BY PARTY NO. 2, CALIFORNIA SECTION, 1876.

Carson to Dayton.
Carson to Steamboat Springs.
Carson to Warm Springs.
McKinney's to Truckee.
Virginia City to Dayton.
Virginia City to Carson.
Virginia City to Steamboat Springs.
Carson City to Rowlands.
Rowland's to Genoa.

From Carson, Nev., to Dayton, Nev.—Atlas-sheet No. 47 D.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Carson.	From Dayton.		
Carson		....	11.85	....	At the capital.
	3.70				
Empire		3.70	8.15	....	
	2.55				
Half-way House		6.25	5.60	....	
	0.55				
Mound House		6.80	5.05	....	Virginia and Truckee Railroad.
	5.05				
Dayton		11.85	....	....	At the post-office.

Carson, Nev., to Steamboat Springs, (via east side Washoe Lake.)

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Carson.	From Steamboat Springs.		
Carson		....	19.91	....	At the capital.
	4.17				
Lake View		4.17	15.74	....	
	10.15				
Washoe		14.32	5.59	....	East side of lake from Lake View to Washoe.
	5.59				
Steamboat Springs		19.91	....	....	Virginia and Truckee Railroad.

Carson to Warm Springs.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Carson.	From Warm Sp'gs.		
Carson		....	....	....	At the capital.
	1.71				
Warm Springs		....	....	....	State-prison.

From McKinney's, Lake Tahoe, Cal., to Truckee, Cal.

	Distance in miles. Between consecutive points.	Distance in miles. From McKinney's.	Distance in miles. From Truckee.	Altitude in feet above sea-level.	Remarks.
McKinney's		....	24.30	....	North of Sugar Pine Point.
	3.48				
Blackwood Creek		3.48	20.82	....	
	3.30				
Saxton's Saw-Mill		6.78	17.52	....	
	2.29				
Tahoe City		9.07	15.23	....	At hotel.
	5.56				
Claraville		14.63	9.67	....	Deserted mining-camp.
	4.74				
Knoxville		19.37	4.93	....	Toll-house, Truckee and Tahoe turnpike road.
	4.93				
Truckee		24.30	....	....	Central Pacific Railroad.

From Virginia City, Nev., to Dayton, Nev.—Atlas-sheet No. 47 D.

	Distance in miles. Between consecutive points.	Distance in miles. From Virginia City.	Distance in miles. From Dayton.	Altitude in feet above sea-level.	Remarks.
Virginia City		....	7.51	....	At the International Hotel.
	3.74				
Silver City		3.74	3.77	....	At the flag-staff.
	1.72				
Johntown		5.46	2.05	....	
	1.37				
Gold Cañon Toll-House		6.83	0.68	....	
	0.68				
Dayton		7.51	....	....	At the post-office.

From Virginia City, Nev., to Carson, Nev.—Atlas-sheet No. 47 D.

	Distance in miles. Between consecutive points.	Distance in miles. From Virginia City.	Distance in miles. From Carson.	Altitude in feet above sea-level.	Remarks.
Virginia City		....	14.47	....	At the International Hotel.
	3.74				
Toll-House, American Flat		3.74	10.73	....	
	10.73				
Carson		14.47		....	At the capital.

From Virginia City, Nev., to Steamboat Springs, Nev.—Atlas-sheet 47D.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Virginia City.	From Steamboat Springs.		
Virginia City		....	11.15	....	At International Hotel.
Toll-House	2.51	2.51	8.64	....	On Geiger grade.
Five-Mile House	3.17	5.68	5.47	....	Do.
Magnolia House	3.22	8.90	2.25	....	Foot of Geiger grade.
Steamboat Springs	2.25	11.15	0.00	....	Virginia and Truckee Railroad.

From Carson City, Nev., to Rowland's, Cal.—Atlas-sheets Nos. 47D and 56B.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Carson City.	From Rowland's.		
Carson		....	28.49	4,665	At the capitol.
Swift's Station	9.41	9.41	19.08	....	On King's Cañon road.
Summit Camp	2.55	11.96	16.53	....	
Spooner's	0.85	12.81	15.68	....	
Glenbrook	2.39	15.20	13.29	....	
Cave Rock	3.32	18.52	9.97	....	
Zephyr Cove	2.33	20.85	7.64	....	
Small's Station	4.15	25.00	3.49	....	
Kearney's Station	0.90	25.90	2.59	....	
Rowland's	2.59	28.49	....	....	

From Rowland's, Cal., to Genoa, Nev., (via Kingsbury grade.)—Atlas-sheet 56B.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Rowland's.	From Genoa.		
Rowland's		....	14.76	....	
Small's Station	3.48	3.48	11.28	....	
Summit Kingsbury grade	3.22	6.70	8.06	....	
Haines's	5.04	11.74	3.02	....	
Genoa Hot Springs	1.14	12.88	1.88	....	
Genoa	1.88	14.76	....	....	

LIST OF ROAD-DISTANCES BETWEEN PROMINENT POINTS, MEANDERED BY PARTY NO. 4, CALIFORNIA SECTION, 1876.

Carson, Nev., to Austin, Nev., routes Nos. 1, 2, and 3.
Mound House, V. & T. R. R., to Dead Horse Well.
Wadsworth, C. P. R. R., to Mason Valley.
Wadsworth, C. P. R. R., to Dead-Horse Well.
Wadsworth, C. P. R. R., to Lodi Mining District.
Wadsworth, C. P. R. R., to Elsworth and Ione.
Austin, Nevada, to Elsworth, Nev., via Lower Reese River Valley.
Austin to Elsworth, via Ione, Nev.
Austin to Schmidtlein's, Kingston Cañon,
Dead-Horse Well to Elsworth, via Old Wellington Road.

ROUTE No. 1.

From Carson City, Nev., to Austin, Nev.—Atlas-sheets Nos. 47*D and* 48 *C & D.*

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Carson City.	From Austin.		
Carson		....	171.23	4,699	Capital of Nevada.
	3.66				
Empire		....	167.57	4,553	On Carson River; number of mill.
	3.45				
Mound House		7.11	164.12	....	Station Virginia and Truckee Railroad.
	5.06				
Dayton		12.17	159.06	4,376	On Carson River; town of.
	16.50				
Cooney's		28.67	142.56	....	Hay Ranch; water; no wood.
	14.15				
Carson River		42.82	128.41	4,070	Log cabin; wood and water; little grazing.
	10.25				
Ragtown		53.07	118.16	4.002	Water; little wood; forage purchased.
	3.87				
Saint Clair's		56.94	114.29	3,989	Bridge; little wood; forage purchased.
	6.28				
School-house		63.22	108.01	3,920	
	6.47				
Hill & Grimes's		69.69	101.54	3,944	Ranch; no wood; good grazing.
	16.51				
Sand Spring		86.20	85.03	3.926	Water, wood, and forage all purchased.
	20.06				
West Gate		106.26	64.97	4.504	Good water; no wood; no grazing.
	3.11				
Middle Gate		109.37	61.86	4,703	Good water; no wood; little grazing.
	3.39				
White Rock		112.76	58.47	4,818	Water; no wood; little grazing.
	7.11				
Cold Spring		119.87	51.36	5,418	Good water; no wood; little grazing.
	10.86				
Patterson's		130.73	40.50	5,213	Ranch on Edwards's Creek; no wood; grazing.
	14.00				
New Pass		144.73	26.50	....	Water in spring.
	9.25				
Mount Airy		153.98	17.25	6,786	Water; little grazing; no wood.
	10.00				
Jacobsville		163.98	7.25	....	Reese River; no wood; little grass.
	7.25				
Austin		171.23	....	6,594	City of.

NOTE.—The above is the usually-traveled route, and the best road between Carson and Austin, excep that from Patterson's to Austin. The route via Smith's Creek (see Route No. 21) should be taken if accommodations are required en route, there being none between Patterson's and Jacobsville

ROUTE NO. 2.

From Carson City, Nev., to Austin, Nev.—Atlas-sheets Nos. 47 *D and* 48 *D.*

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Carson City.	From Austin.		
Carson		....	174.16	4,699	
Dayton	12.17	....	161.99	4,376	See Route No. 1.
Old Fort Churchill	21.39	33.56	140.60	4,258	On Carson River, (deserted.)
Bucklands'	1.11	34.67	139.49	4,151	Toll-bridge over Carson. Ranch.
Old Well	11.19	45.86	128.30	....	Houtons, (deserted,) no grass or wood.
Carson Lake	14.50	60.36	113.80	3,883	Little grass; poor water; no wood.
Sulphur Spring	13.81	74.17	99.99	3,972	Road station; wood and forage purchased.
Sand Spring	8.00	82.17	91.99	3,926	Road station; water, wood and forage purchased.
* * * *					
Patterson's	44.53	126.70	47.46	5,213	See Route No. 1.
Antoines	14.37	141.07	33.09	6,517	Smith Creek, Milk Ranch; forage must be purchased.
Birchini's	22.32	163.39	10.77	5,743	Reese River; ranch; no timber; forage must be purchased.
Half-way House	5.08	168.47	5.69	5,726	Well; no wood.
Austin	5.69	174.16	....	6,594	Wood and forage purchased.

From Buckland's to Sand Spring is a deserted road and without accommodations at present, between Bucklands' and Sulphur Springs, the first telegraph and old stage road. Also, from Buckland's, Route No. 1, can be joined *via* Gates, on Carson River, (8 miles,) and striking the first route between Coney's and Log Cabin, (10 miles from Gates,) about six miles from Log Cabin.

ROUTE NO. 3.

From Carson City, Nev., to Austin, Nev.—Atlas-sheets Nos. 47 *D and* 48 *D.*

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Carson City.	From Austin.		
Carson		176.34	....	4,699	Capital of Nevada.
* * * *					
Saint Clair's Station	56.94	119.40	....	3,989	See route No. 1.
Crossing Carson	3.72	115.68	60.66	3,978	Bridge; ranch near.
Stillwater	13.71	101.97	74.37	3,954	County seat of Churchill County, Nev.
Mountain Well	14.55	87.42	88.92	....	Poor water; wood; no grazing.
Summit	0.95	86.47	89.87	5,884	Wood; no water or grass.
West Gate	21.50	64.97	111.37	4,504	Good water; no wood; forage purchased. See Route No. 1.
* * * *					
Austin	64.97	....	176.34	6,594	City of.

Ranch about one-fourth mile beyond "Crossing."

Old mining town, La Plata, 3 miles from "Summit," is reached by road that turns to the north at this point.

There is a telegraph station at Stillwater, and this road follows the telegraph line to West Gate, thence to Austin the telegraph is *via* New Pass and Mount Airy. This was the last route of the Overland Stage Company.

From Stillwater there is a road (little traveled) to Sand Spring, distance 21 miles.

From Mound House to Dead-Horse Well.—Atlas-sheet No. 57 A.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Mound House.	From Dead-Horse Well.		
Mound House		....	94.49	....	Station, Virginia and Truckee R. R.
Dayton	5.06	....	89.43	4,376	Town of. Carson River bridge.
Toll-Gate	11.02	16.08	78.41	4,260	On Carson River; ford near.
Churchill Cañon	9.84	25.92	68.57	....	Water and little wood; no grass.
Forks of road	3.46	29.38	65.11	4,272	
Schwartz	6.19	35.57	58.92	....	First ranch in Mason Valley.
First Crossing	5.12	40.69	53.80	4,345	Portion Walker River; no timber; grazing.
Mason's	6.00	46.69	47.80	4,348	Ranch.
Geiger's	1.40	48.09	46.40	4,352	Near second ford (main) Walker River.
Lee's Mill	0.60	48.69	45.80	4,350	Water-mill.
Indian Agency	17.80	66.49	28.00	4,120	Lower crossing W. R. ford.
Double Spring	9.00	75.49	19.00	....	Water; no wood.
Dead-Horse Well	19.00	94.49	....	4,117	Water; no wood or grazing.

From Dayton, a toll-road is being constructed through Mason Valley toward Bellville.

Dead-Horse Well is called 50 miles from Bellville. This road is now constructed to its junction with the road from Bucklands to Mason Valley.

From Churchill Cañon the left-hand road, making a small detour to the east, passes a well and station on the Buckland road, (also) 2 miles from Churchill Cañon. The construction of bridges, as contemplated, over the Walker River, near Lee's Mill will materially improve and shorten this toll-road.

From Wadsworth, Nev., to Mason Valley Post-Office.—Atlas-sheets Nos. 48 C & 57 A.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Wadsworth.	From Mason Valley Post-Office.		
Wadsworth		....	56.54	4,102	Station, C. P. R. R.
Bucklands	27.08	....	29.46	4,151	Ranch; toll-bridge over Carson.
Road from Dayton { First Fork	7.25	34.33	22.21	4,259	Well of good water; station.
Road from Dayton { Second Fork	2.00	36.33	20.21	4,272	
Schwartz	6.19	42.52	14.02	....	First ranch in Mason Valley.
First Crossing W. River	5.12	47.64	8.90	4,345	Grazing; no timber.
Mason	6.00	53.64	2.90	4,348	Ranch.
Geiger	1.40	55.04	1.50	4,352	Near second ford (main) Walker River.
Mason Valley Post-Office	1.50	56.54	....	....	Small settlement.

Stockton Well, an old stage-station on the overland route, is near this road, and about nineteen miles from Wadsworth; the station is deserted.

From Wadsworth, Nev., to Dead-Horse Well.—Atlas-sheets Nos. 48 C & 57 A.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Wadsworth.	From Dead-Horse Well.		
Wadsworth		....	80.68	4,102	Station, C. P. R. R.
	15.70				
Desert Well		....	64.98	4,031	No wood or grazing.
	6.45				
Ragtown		22.15	58.53	4,002	Carson River; little wood; forage purchased.
	3.87				
Saint Clair Station		26.02	54.66	3,989	Bridge over Carson; little wood; forage purchased.
	6.28				
School-House		32.30	48.38	3,920	
	6.47				
Hill & Grimes		38.77	41.91	3,944	Ranch; no wood; good grazing.
	10.20				
Sulphur Spring		48.97	31.71	3,972	Water; no wood or grass.
	3.45				
Salt Well		52.42	28.26	4,020	Poor water; no wood or grass.
	5.84				
Cox's Station		58.26	22.42	4,379	No wood or water; little grazing.
	5.16				
Summit		63.42	17.26	5,602	No wood or water; little grazing.
	3.30				
Deep Hollow		66.72	13.96	5,244	No wood or water; little grazing.
	13.96				
Dead-Horse Well		80.68	....	4,117	Water; no wood or grazing.

The above is the road over which freight is now transported from Bellville, Nev., Dead-Horse Well being about fifty miles from Bellville. Water for the use of the stations is hauled to Salt Well, Cox's Station, and Summit, from near Sulphur Springs, and to Deep Hollow from Dead-Horse Well.

From Wadsworth, Nev., to Lodi, Nev.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Wadsworth.	From Lodi.		
Wadsworth		....	108.29	4,102	Station on Central Pacific Railroad.
	15.70				
Desert Well		....	92.59	4,031	Water; no wood or grass.
	6.45				
Ragtown		22.15	86.14	4,002	Carson River; little wood; forage purchased.
	3.87				
Saint Clair Station		26.02	82.27	3,989	Bridge over Carson; forage purchased.
	12.75				
Hill & Grimes		38.77	69.52	3,944	Ranch; forage purchased.
	16.51				
Sand Spring		55.28	53.01	3,926	Forage, wood, and water purchased.
	20.06				
West Gate		75.34	32.95	4,504	Good water; no wood; forage purchased.
	11.96				
Muddy Spring Summit		87.30	20.99	6,219	Winter spring ½ mile south; little wood or grazing.
	7.46				
Chalk Well		94.76	13.53	5,690	Water; no wood or grazing.
	10.25				
Welsh's		105.01	3.28	5,236	Water; no wood; little grazing.
	3.28				
Lodi		108.29	....	5,356	Mines; no wood; no water; little grazing.

From Wadsworth, Nev., to Ellsworth and Ione, Nev.—Atlas-sheet No. 57 *B.*

	Distance in miles. Between consecutive points.	Distance in miles. From Wadsworth.	Distance in miles. From Ellsworth and Ione.	Altitude in feet above sea-level.	Remarks.
Wadsworth		....	108.76	4,102	Station on C. P. R. R.
Desert Well	15.70	....	98.06	4,031	Water; no wood or grass.
Ragtown	6.45	22.15	86.61	4,002	Carson River; little wood; forage purchased.
Saint Clair Station	3.87	26.02	82.74	3,989	Bridge over Carson; little wood; forage purchased.
Hill & Grimes	12.75	38.77	69.99	3,944	Ranch; little wood; forage purchased.
Sand Spring	16.51	55.28	53.48	3,926	Forage, wood, and water purchased.
West Gate	20.06	75.34	33.42	4,504	Good water; no wood; forage purchased.
Muddy Spring Summit	11.96	87.30	21.46	6,219	Winter spring ½ mile south; little wood or grazing.
Chalk Well	7.46	94.76	14.00	5,690	Water; no wood or grazing.
Burnt Cabin Summit	4.00	98.76	10.00	6,552	Scant timber; no water.
Forks road to Ellsworth	0.50	99.26	9.50	....	
Ellsworth	9.50	108.76	....	6,871	Mining town; forage, &c., purchased.

From "forks of road" Ione is distant 14.5 miles.

From West Gate a route may be taken to Chalk Well, as follows: To White Rock, 6.500 miles; water; no wood or grazing; East Gate, 2.710 miles; water; little wood, (ranch;) Chalk Well, 14.000 miles; water; no wood or grazing; total, 23.21 miles.

From Austin, Nev., to Ellsworth, Nev.—Atlas-sheets Nos. 48 *D and* 57 *B.*

	Distance in miles. Between consecutive points.	Distance in miles. From Austin.	Distance in miles. From Ellsworth.	Altitude in feet above sea-level.	Remarks.
Austin		....	55.21	6,594	City of.
Silver Age	8.69	... .	46.52	6,014	Well; forage, &c., purchased.
Crowley's	4.00	12.69	42.52	....	Ranch, Reese River.
Summit	11.25	23.94	31.37	6,253	Scant timber; no water.
Peterson's	9.56	33.50	21.81	6,137	Ranch; forage, &c., purchased.
Cabin	10.05	43.55	11.76	6,597	Spring; no wood; little grazing.
Ellsworth	11.76	55.31	....	6,871	Mining town; wood plenty; forage, &c., purchased.

Road but little used. Grade is good.

ROUTE No. 1, VIA IONE, NEV.

From Austin, Nev., to Ellsworth, Nev.—Atlas-sheets Nos. 48 *D and* 57 *B.*

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Austin.	From Ellsworth.		
Austin		....	60.54	6,594	City of.
Silver Age	8.69	....	51.85	6,014	Well; forage, &c., purchased.
Ahle's Ranch	11.77	20.46	40.08	5,990	Reese River; forage, &c., purchased.
Elkhorn	5.680	26.14	34.40	6,123	Do.
McMahon's	17.46	43.60	16.94	6,552	Do.
Summit	4.690	48.29	12.25	7,488	Timber; no water.
Ione	3.250	51.54	9.00	6,844	Mining town; wood plenty; forage, &c., purchased.
Ellsworth	9.00	60.54	....	6,871	Do.

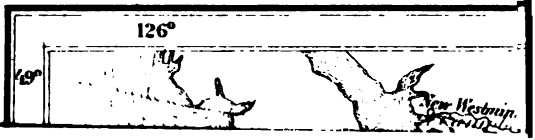
Good wagon-road.
Buck-board carries the mail and passengers from Ellsworth to Austin.
Austin is distant 88 miles from Battle Mountain; Central Pacific Railroad is connected by stage-line.
Ranches are found at short intervals from Ahles to McMahon's, along Reese River.

From Austin, Nev., to Schmidtlein's Ranch.—Atlas-sheet No. 48 *D.*

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Austin.	From Schmidtlein's Ranch.		
Austin		....	28.29	6,594	City of.
Silver Age	8.69	....	19.60	6,014	Well; forage, &c., purchased.
Mouth Big Creek Cañon	3.80	12.49	15.80	....	Water; little wood and grass.
Forks of Big Creek	2.00	14.49	13.80	6,982	Water; little wood and grass.
Summit, (south fork)	3.20	17.69	10.60	8,675	
Sterling Mill	9.60	27.29	1.00	6,818	Water; little wood and grass.
Mouth Kingston Cañon, Schmidtlein's Ranch.	1.00	28.29	....	6,220	Water and grass.

Schmidtlein's Ranch is on the west side of Big Smoky Valley.
This is the middle pass through the Toyabe range, from Reese River Valley to Big Smoky Valley. The northern one is at Austin and the southern one by Ophir Cañon.

U.S. GEOGRAPHICAL SURVEYS.



From Dead-Horse Well to Ellsworth, Nev.—Atlas-sheets Nos. 57 A and 57 B.

	Distance in miles.			Altitude in feet above sea-level.	Remarks.
	Between consecutive points.	From Dead-Horse Well.	From Ellsworth.		
-Horse Well		....	37.77	4,117	Good water; no wood or grazing.
	10.65				
t Springs		....	27.12	4,212	Water; salt grass; no wood.
	15.32				
Well		25.97	11.80	....	Not used; no wood and little grass.
	8.30				
mmit		34.27	3.50	7,602	Timber; little grazing.
	3.50				
lsworth		37.77	....	6,871	Mining town; wood, water, and forage.

d-Horse Well was a station on the Wellington stage road from Walker River to Reese River; it o on the direct road from Wadsworth to Bellville, and from Mason Valley to Bellville, 50 miles the latter.

PROGRESS MAP.

he changes noted on this sheet are, in addition to the marking of as occupied and proposed for the season of 1877, and the stage of ecution of map results, the positions of the present Indian agencies, naming of railroads, and an addition of practical data showing the nges in lines of communication, military posts, &c., within the year. e short season rendered it impracticable to add so large an area as al to that already covered in previous years by the several topophical parties, and my own time was spent principally with the party rating in the Lake Tahoe region and in the Washoe mining district, er concluding the organization of the Colorado section.

he immediate vicinity of Lake Tahoe has been so often described, the later maps will afford so much that is an improvement to the sent idea of its mountain picturesqueness, that I need only add regret that the spoliation of the forests along its shores has become rapid, in aid of the mines of the Comstock, that shortly the horizon m lake-level will be bare of the covering that has lent so much to the ural beauty of this peculiarly interesting region. Indeed, could the e of the Government be again made perfect to this part of its domain, might be justified in recommending its segregation from the "publands," that the natural beauty of the forest might be permanently erved as a part of a lake region so unique.

PROFILES.

he aneroid profiles joining most of the points of importance within immediately adjacent to the field of survey have been prepared, have become a matter of office record.

special profile-map of the continental divide from Gray's Peak, Coldo, to latitude 35° in New Mexico, has been prepared, showing the vations of the prominent peaks and passes, and upon it is projected profile of the ridges facing the plains from the head of the Arkansouthward to the latitude above mentioned.

s the passes leading westward and lying between Gray's Peak and rman, the highest point on the Union Pacific Railroad, (8,242 feet,) known to be each of greater elevation than those necessary to be ssed, as shown by the sketch, in going southward until near latitude , it appears that any through railroad route to the Pacific, south of Union Pacific Railroad, will necessarily encounter elevations equal those given.

It does not seem practicable to avail of any new pass for a through western line of railroad between latitude 35° and 40°, except that at the head of Pass Creek, a southern branch of the Huerfano that heads near the source of the Sangre de Cristo Creek, and where, by means of tunneling, a transit of the summit should be made, at an elevation not exceeding an altitude of approximately 9,100 feet above sea-level.

NATURAL RESOURCES.

Upon the sheets in colors, showing the natural distinctions of the surface occupied, the following divisions are made:

1. *Arable.*—This refers to soil susceptible of cultivation by the use of water, when it is apparent that the supply is adequate, assuming that irrigation is necessary.

2. *Grazing.*—Of the various grades, often infringing upon the timbered area.

3. *Timber.*—The gradations in amount, size, and quality cannot be shown.

4. *Arid and barren.*—This embraces that part of the surface absolutely valueless for agricultural purposes, and includes desert wastes and rock exposures.

The positions of mines in place and placer are at present shown only on the regular topographical sheets.

The topographical sheet upon which these divisions are marked is a reproduction from the original sheets regularly issued. A legend is attached to the case of maps, giving the geographical locality of each. A description, supplemented now by the maps themselves, of sheets 61B, 61Cc, 65D, 70A, and 70C, is given in the last annual report.

BAROMETRIC ALTITUDES.

Work in the meteorological branch has been confined principally to the taking of observations with a view to their subsequent computation and determination therefrom of differences of altitude between known points and those at which original observations have been taken. Good progress has been made.

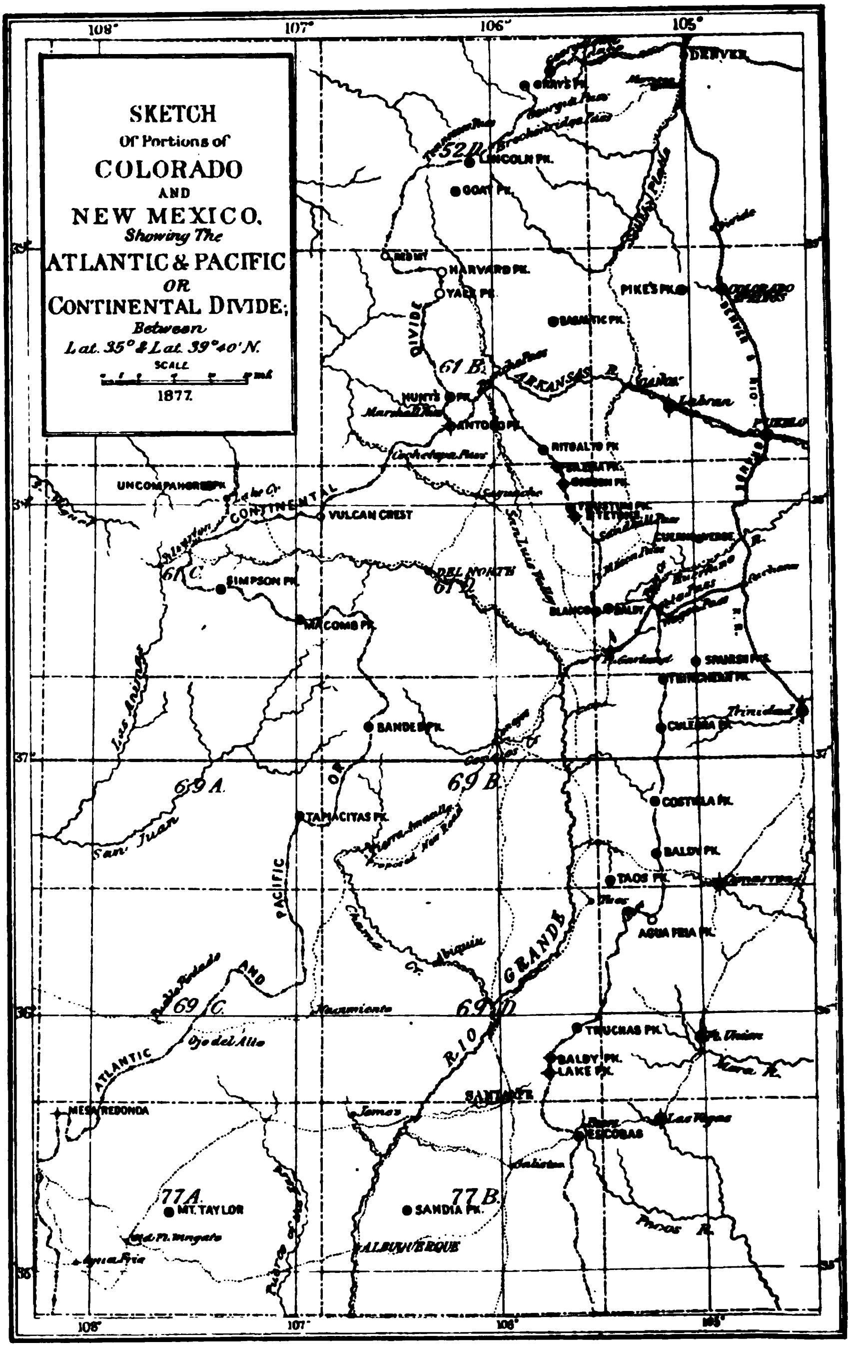
The altitudes are at once used in the construction of the mountain parts of the map, and upon the atlas-sheet the altitudes of the principal settlements and other marked points are noted, while from time to time the altitudes of prominent peaks and other natural objects will be published in list form.

The Signal-Office, through the courtesy of General Albert J. Myer, Chief Signal-Officer, has kindly furnished transcripts of observations taken at a number of stations contiguous to the field of survey.

MINING INFORMATION.

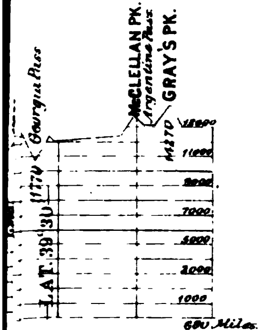
Fifteen districts have been visited and located by the several parties. The cursory examination that may be carried out hastily, in a district usually not long discovered, has been made, and the facts gathered made the subject of a report.

At the Comstock Lode, made famous from its large production of the precious metals, gold and silver, more extensive examination as to the engineering features of its mining industry has been instituted; added to the overground survey of the contour and superficial improvements, underground examinations along profile lines separated one hundred feet are in progress, and the circumstances of the mining openings upon the various levels will be noted, and the marked features discovered will be illustrated graphically. The conditions of ventilation and drainage will be made a matter of special study, as well as the application of



SKETCH
Of Portions of
COLORADO
AND
NEW MEXICO.
Showing The
ATLANTIC & PACIFIC
OR
CONTINENTAL DIVIDE;
Between
Lat. 35° & Lat. 39°40′ N.
SCALE
1877.
108°
107°
106°
105°
DENVER
LINCOLN PK.
GOAT PK.
HARVARD PK.
YALE PK.
PIKE'S PK.
COLORADO SPRINGS
DIVIDE
61 B.
ARKANSAS R.
PUEBLO
UNCOMPAHGRE PK.
CONTINENTAL
VULCAN CREST
61 C.
SIMPSON PK.
DEL NORTE
61 D.
BLANCO
SPANISH PK.
Trinidad
BANDERA PK.
69 A.
69 B.
San Juan
Las Animas
TAMACITAS PK.
COSTILLA PK.
BALDY PK.
TAOS PK.
AGUA FRIA PK.
OR
PACIFIC
AND
ATLANTIC
69 C.
69 D.
RIO GRANDE
TRUCHAS PK.
BALDY PK.
LAKE PK.
SANTA FE
Las Vegas
MESA REDONDA
77 A.
MT. TAYLOR
77 B.
SANDIA PK.
ALBUQUERQUE
Pecos R.
Abiquiu
Jemez

WEST OF THE 100TH MERIDIAN.



machinery to the lifting of heavy weights from below the surface and the conditions of practice in the reduction of ores. If time and means permit, nothing will be left undone in the full and fair investigation of the present condition of mining industry in this section, as evidenced by work already prosecuted.

The Sutro Tunnel, well known as the most extended work of its kind in American mining, will be examined in detail, and the rock-specimens gathered during its progress are likely to throw much light on the character of the several volcanic beds or "country rock" that make up the casings of the ore-bearing matter. The next annual report will give the progress made up to that date, while the finished results will endeavor to show in shape for permanent reference the present condition of this industry, now so well recognized in the western interior.

In this duty I have been assisted by Mr. John A. Church, mining engineer, who has taken up the underground work with a commendable energy, and Anton Karl, general service, U. S. Army, who has been engaged in completing plane-table sheets, begun in the year 1876.

THE EAGLE AND WASHOE VALLEY MINING DISTRICT, NEVADA.

[From notes by A. R. Conkling.]

This district was discovered and organized in August, 1875, since which time the North Carson has been worked continuously. Its post-office is Carson, Nev. It is distant from railroad communication three miles. The nearest practicable route is a wagon road, direct to the Carson Mine, from the Virginia and Truckee Railway. It is bounded on the north by the divide between Washoe Lake and Carson Plain; on the south by Carson River; on the east by the Como Mountains; on the west by the Eastern Summit Range. Area, about 25,000 linear feet, now taken up in North Carson Mine. Long and narrow in shape, the trend is generally northeast and southwest. Other mining-ledges are found in the vicinity, on the southern slope of the foot hills, with a general trend north and south. The general direction of lodes, deposits, and stratifications is northeast and southwest. The ore is richer, and the vein enlarges in descending. The wall-rock is granite. Its slope is nearly vertical. The clayey wall inclines slightly to the east. In age, the country rock is metamorphic, granite, and hornblendic granite. No fossils are found. Ores are worked by the free process.

No water-level has yet been reached. Chloride of silver is the chief ore, with some sulphides. Silver is the principal metal, with a little malachite incrustating the wall-rock. The principal mines now worked are the Montreal, Emerald, Clear Creek, Niagara, (described in Whitehill's report,) and the North Carson. The North Carson is situated 3 miles due north of Carson City. It has one double-compartment shaft, 305 feet deep. The walls of shaft are well timbered. Timber can be hauled to the mine from flume at the rate of $12 per 1,000 feet. At every 100 feet in the shaft there is a station. At the foot of the hill there is a tunnel 610 feet long, not yet (September, 1876) reached by the shaft. Two hundred feet from the mouth of the shaft a little rock has been broken, *i. e.*, sufficient to reach the vein. At 100 feet level there is a drift 320 feet long. The mine has good ventilation.

No ore has been sent away from this mine as yet. Vein of ore varies from 4 to 5 feet. Seventy-five thousand dollars has been expended in the mineral development of the North Carson Mine. The average cost of milling labor per day is $4. Cost per foot for sinking a shaft on a main vein is from $60 to $70. Average cost per foot for running a drift on a main vein, $30. Hay is $30 per ton. Oats, 3 cents per pound; an abundant supply of both. Facilities for raising farm-produce are good.

Timber and wood abundant. Water at North Carson Mine is brought from Virginia water-hoisting works. Main tapped 1¾ miles from Carson. There is one stage and several freight lines. Five churches, 2 school-houses, many stores, and 2 banking-houses. The Indians are those of the Washoe and Shoshone tribes, and are few in number. The principal silver-mining companies are the North Carson, Ayres and Hopkins, Gould and Barnhart, Ida Ayres, All Right, Ayres's Consolidated, Huston, and Montreal and Emerald. These companies are incorporated under the laws of California.

NATURAL HISTORY.

In geology, Mr. A. R. Conkling submits a report of his observations made in the Sierra Nevada, in the vicinity of Lake Tahoe and to the southward, and has collected a number of fossils. His report upon the results of an examination of a number of microscopical section of rocks from various localities is herewith.

Mr. H. W. Henshaw has made an ornithological report as the result of his season's labor, and, as well, has collected specimens in other departments of zoology. The results from further examinations by Dr. J. T. Rothrock and Prof. F. W. Putnam, the one in botany, the other of the archæological collections, with their colaborers, will appear in volumes 6 and 7.

The following gives a list, as prepared by Mr. Henshaw, of the various lots and specimens forwarded by the expedition to the Smithsonian Institution; all of which have been donated to its museum, their practical importance to the survey having ceased with the examination and reports made thereupon. The list is taken from the records of this office and those of the Smithsonian Institution:

List of natural-history collections forwarded to the Smithsonian Institution during the years 1871 to 1876, inclusive.

Subjects.		1871.	1872.	1873.	1874.	1875.	1876.	Total specimens.
Vertebrate fossils	specimen	......	......	......	......	500	......	500
	lot	......	......	......	......	1	......	
Invertebrate fossils	specimens	126	1,420	1,566	250	......	......	3,368
Crustacea	specimens	......	......	......	......	100	200	300
	lots	......	......	......	......	1	14	
Mollusca	specimens	......	......	600	250	1,000	150	3,000
	lots	......	......	66	23	95	15	
Mammals	specimens	9	21	135	52	43	10	*270
Birds and mammals, (alcoholic,) specimens.		......	......	......	......	26	4	30
Mammal crania	specimens	......	......	37	3	18	2	60
Birds	specimens	60	522	659	1,055	793	150	3,239
Bird crania, (sterna, &c.)	specimens	......	4	31	22	9	2	68
Bird-skeletons	specimens	......	......	4	......	......	......	4
Bird-embryos	specimens	......	......	......	......	5	......	5
Bird-nests	specimens	......	10	20	6	......	......	36
Bird-eggs	specimens	12	20	193	11	14	......	250
Reptiles, (batrachians)	specimens	135	550	950	750	750	83	3,218
	lots	27	109	192	140	153	8	
Fishes	specimens	15	275	850	650	800	350	2,940
	lots	3	48	109	91	116	49	
Hymenoptera	specimens	......	......	450	......	790	50	500
	lots	......	......	43	......	......	3	
Lepidoptera	specimens	......	......	288	......	483	......	771
	lots	......	......	144	......	162	......	
Diptera	specimens	......	......	50	......	......	......	50
	lots	......	......	13	......	......	......	
Coleoptera	specimens	1,300	100	4,500	4,200	1,200	2,000	13,300
	lots	135	5	240	211	18	34	
Orthoptera	specimens	......	......	500	......	......	......	500
	lots	......	......	48	......	......	......	
Arachnida	specimens	......	......	250	......	100	......	350
	lots	......	......	26	......	16	......	
Botanical specimens	specimens	......	......	......	......	......	......	*11,000
	lots	......	......	......	......	......	......	

* Approximate.

PUBLICATIONS.

During the year the following maps have been published:
Progress map of 1877.
Profile map (continental divide from Gray's Peak to latitude 35°.)
Topographical atlas-sheets 53 C, 61 D, 65 D, 69 B, 70 A, 70 C, 77 B.

The natural resources of five of these sheets, in colors, will be found accompanying the edition of the annual report, printed and placed at the disposal of this office.

Maps in color showing the natural advantages of the area delineated in sheet 61 C_c, (San Juan,) and 61; (B,) Upper Arkansas Valley, are also added.

The volume numbered four (Paleontology) has passed through the press. Proof of nearly half of volume II has gone to stereotype. The proof of a portion of the "Star Catalogue" mentioned in my last report has been read, and this valuable catalogue will be in the hands of observers during the coming season, should longitude and latitude observations be prosecuted.

Two thousand copies of my annual report (Appendix J J, annual report Chief of Engineers for 1876,) have been published, with a folio of the regular atlas-sheets issued during the year ending June 30th, 1876.

The following atlas-sheets, seventeen in number, are in various stages of completion, viz: 47 B, 47 D, 48 C, 48 D, 52 D, 62 A, 62 C, 69 A, 69 C, 73 A, 73 B, 73 C, 73 D, 77 C, 77 D, 78 A, 84 A.

A number of sheets, enumerated below, have been plotted in various scales, and have either been published or are awaiting publication, as follows: Lake Tahoe region, 1 inch to 1 mile; route of party No. 1, California section, 1875, 1 inch to 4 miles; map of Virginia City, Nev., and vicinity, 1 inch to 500 feet; three plane-table sheets, Virginia, Nev., and vicinity, 1 inch to 1,000 feet; preliminary map of portions of northern Utah and southern Idaho, (for field use;) sketch of cave in Nevada; sketch of personal-equation apparatus; plan of Ogden observatory; three sheets giving positions of astronomical monuments; detailed topographical sheet showing results of Colorado River and Grand Cañon exploring party of 1871.

CONCLUSION.

As regards the progress toward completion of the topographical atlas of the area of territory west of the 100th meridian, the progress-map, herewith, shows the advance made in that direction. The possibility of a more or less minute topographical survey of all of this extended region has not yet been made mandatory by legislative act, but Congress has appropriated money for a number of years. The use of this fund is limited to a fiscal year, and hence, unless an additional appropriation is each year made, which is often unknown until the current year has nearly expired, the project of operations, as a part of which the retention of skilled employés is requisite, cannot be made, until a date often later than the period terminating their office-work which is needed in the reductions of the previous season's field-work; and this is usually so late that full advantage cannot be taken of the entire summer-season. By an increase of assistants enlisted in the general service and the detail of a number of engineer and other officers requisite for the command of the number of field-parties each year engaged, the expenditure for additional service can be limited to the small number of scientists engaged in special

duties, and that of computers and draughtsmen engaged in the technical labors necessary to the rapid production of results. Without adverting to the advantage to the military service growing out of extended topographical surveys, it seems practical to urge the propriety of placing the item for the continuation of this work upon the "Army bill," which usually becomes a law earlier during the session of Congress than the sundry civil bill, (so called,) that frequently is not approved earlier than the middle of June, while parties for the field should be en route during the early part of May.

ESTIMATE.

For continuing the geographical survey of the territory of the United States west of the one hundredth meridian, provided the supply-branches of the War Department shall assist as heretofore; being for field and office work, and for the preparation, engraving, and printing of the maps, charts, plates, cuts, photographic-plate and other illustrations for reports; for temporary office-room at points remote from Washington, D. C., and the purchase at nominal rates of sites for field-observatories authorized by the Department; for the fiscal year ending June 30, 1879	$120,000 00

As follows:

For expenses of parties in the field	$45,000 00
For office-expenses including salaries	10,500 00
For transportation, including purchase of animals	10,000 00
For material for outfits	6,500 00
For subsistence on expeditions	5,500 00
For forage, winter-herding, fuel, storage, &c	7,500 00
For purchase of instruments	6,000 00
For repair of instruments	1,000 00
For temporary office-room at points remote from Washington	1,000 00
For erection of observatories and monuments at astronomical and geodetic stations	4,500 00
For purchase of sites for observatories	1,000 00
For preparation of maps, charts, &c	6,000 00
For engraving and printing maps, charts, photographic-plate and other illustrations for reports	10,000 00
For contingencies, (field and office)	5,500 00
Total	120,000 00

FINANCIAL STATEMENT.

Amount expended from appropriation for the fiscal year ending June 30, 1877, and from appropriation made available March 3, 1877	$35,329 87
Amount remaining unexpended July 1, 1877, from appropriation for continuing the geographical survey of the territory of the United States west of the one hundredth meridian for fiscal year ending June 30, 1878.	43,492 64

All of which is respectfully submitted.

GEO. M. WHEELER,
First Lieut. Corps of Engineers, in Charge.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

APPENDIX A.

EXECUTIVE AND DESCRIPTIVE REPORT OF LIEUTENANT ERIC BERGLAND, CORPS OF ENGINEERS, ON THE OPERATIONS OF PARTY NO. 1, COLORADO SECTION, FIELD SEASON OF 1876.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL SURVEYS WEST OF 100TH MERIDIAN,
Washington, D. C., April 15, 1877.

SIR: I have the honor to submit the following report of operations of party No. 1, Colorado section, during the last field season:

Owing to the late date at which the appropriation for the survey became available,

the party was not organized until the latter part of August, 1876, at the Rendezvous Camp at Fort Lyon, Colo., and consisted of myself as executive officer and field astronomer; Louis Nell, chief topographer; Francis Klett, assistant topographer; William C. Niblack, meteorologist; A. K. Owen, odometer recorder; two packers, one cook, one teamster, and two enlisted men belonging to Company D, Nineteenth Infantry.

As the field season would be necessarily short, only a limited area could be covered and completed; hence that assigned to me embraced portions of several atlas-sheets, for the completion of which, sufficient topographical data had not been previously obtained. These incomplete sections lie in the southeast corner of atlas-sheet "52 D," southwest corner of "53 C," western portion of "62 A," northeast portion of "61 D," and northwestern portion of "62 C." As it was necessary to go as far north as latitude 39° 20′ and to the south as far as latitude 37° 40′, it seemed advisable to complete the northern section first before the snow would interfere with our movements, and triangulation and topographical work; then to proceed southward and accomplish the work required in the San Luis and Wet Mountain Valleys. Subsequent events proved this surmise to be correct, as we had barely finished our work in the northern portion when we were greeted with a snow-storm on reaching Fairplay, the 13th of October.

After completing the organization, the party proceeded up the Arkansas Valley from Fort Lyon to Pueblo, Col. At this place several triangulation stations were occupied and monuments erected on prominent points in the vicinity. From Pueblo the main party proceeded to Cañon City; thence along the Fairplay road to the 17-mile ranch on Currant Creek, at which point we left this road and proceeded northeastwardly along the road to High Creek and camped on this latter creek, a short distance above the cañon. Before reaching Cañon City, a side party was detached in charge of the chief topographer which proceeded up Beaver Creek to the vicinity of its source, occupying the principal peaks south of Pike's Peak, and establishing the courses and drainage of the streams which flow south from this range and empty into the Arkansas River between Pueblo and Cañon City. The side party having joined the main party at High Creek, we proceeded along the Colorado Springs road to Florissant Post Office. From this point a number of topographical stations were occupied, and the surrounding country thoroughly surveyed.

By your orders Mr. Klett was directed to proceed to Washington on the 1st of October, and he left the party at this place; at the same time I sent one of the enlisted men back to Fort Lyon, since his services in the field were no longer required. From Florissant, after crossing the South Platte River, we proceeded up Tarryall Creek to the junction of Rock Creek, then up this latter creek some 5 miles, where camp was established, and from whence the ascent of the Twin Cones was made.

From Rock Creek the party proceeded westwardly across the upper end of South Park to Fairplay, thence south via the Salt Works and Trout Creek Pass into the Upper Arkansas Valley, down this valley to the junction of the South Arkansas River, thence through Puncho Pass into the San Luis Valley, and down the valley to the Mosca Pass. From camps in the latter valley several prominent peaks of the Sangre de Cristo Range were occupied, a road to Sagauche meandered, and several mines visited and examined.

Passing through the Mosca Pass we entered the Wet Mountain Valley and proceeded to Rosita, where the main camp was established, from which side parties were sent out to occupy the necessary points in the Sangre de Cristo and Wet Mountain Ranges and Cuerno Verde Peak. Here the mines were also examined, and information gained as to their yield and prospects.

From Rosita the party moved to Cañon City by way of the Oak Creek Road, thence by the road which crosses the head of Little Fountain Creek to Colorado Springs. Here a base-line was measured and connected with our system of triangles, as well as with the astronomical monument, and Pike's Peak was ascended and occupied as a triangulation-station. From Colorado Springs the party proceeded to Pueblo and Fort Lyon, which latter place was reached December 10. The property was then disposed of according to your orders, and the party disbanded.

The results obtained during the field season may be briefly enumerated as follows:

Ten triangulation stations were occupied, at which repeated angles were measured by means of an 8-inch transit theodolite by Buff & Berger, reading to 10 seconds of arc. Fifty-one topographical stations were occupied and located by angles to the triangulation stations. The route of the party was meandered and measured with the odometer throughout. At Colorado Springs a base-line over 12,000 feet long was carefully measured. The usual meteorological observations were taken in camp, on the march, on divides, and mountain stations, in accordance with your printed instructions. The mines on the west slope of the Sangre de Cristo Range, and those at Rosita, were visited and examined.

Tarryall Creek was gauged at camp 12, near McLoughlin's Ranch, on October 8

and its volume found to be 27.5 cubic feet per second, which may be considered as the minimum amount, as rain had not fallen for several weeks previously.

The geology, climate, and agricultural resources of this region have been so ably described in previous annual reports and also by Professor Stevenson in Volume III of your quarto reports, that any detailed description by me would be superfluous, hence I will merely remark that an abundance of water, wood, and grass was found at nearly all of our camps, except in the San Luis Valley. The small valleys along the streams which empty into the South Platte and Arkansas are occupied by settlers whose principal pursuit is stock-raising. Considerable portions of these valleys have been fenced in and are utilized for hay-land and pasturage, as during severe winters, when there is a heavy snow-fall, the cattle must be fed on hay until the snow is reduced in depth. Deer and other game were frequently seen in the mountains after the 1st of November, and herds of antelope in the upper portions of the San Luis Valley, and on the plains east of Pueblo. The streams in this section are generally not well stocked with fish, none being found in some of the larger, as Tarryall Creek. An instance of the devastating effect of violent rain-storms or cloud-bursts was observed at Duck Lake on the Tarryall Creek. In the fall of 1875 a heavy shower of limited area burst over the mountains on the east side of the creek, the water from which brought down so much earth and loose material that the stream was choked up, and the water spread over the valley, converting some hundreds of acres of hay-land into a miry swamp. The temperature during the day in September and October was moderate and pleasant, the nights cool and refreshing. But little rain fell during these months, and the sky was generally free from clouds, which circumstance greatly facilitated our triangulation and topographical work. In November, especially during the latter part of the month, the thermometer ranged during the day from 50° to below the freezing-point, while at night and on some mountain stations the mercury went down to zero and below. Frequent snow-storms also interfered with our work and movements, and made it extremely unpleasant for all members of the party, as well as necessitating the purchase of forage for the animals when the ground was covered with snow.

MINES.

The first mines visited are situated in the new district, in the vicinity of the head-waters of the North Creston Creek. This district was (October 27) about to be organized under the name of Creston district. First discoveries were made in May, 1875, and a number of prospecting shafts had been opened. But little ore had been taken out up to the time of my visit, as there is no mill at the mines and the ore is not rich enough to warrant the cost of shipment to any distance. Some of the quartz which has been milled gave a yield of $12 to $15 per ton. Three to four thousand dollars have been expended in completing lines of communication to the mines. Timber is convenient and abundant on the slopes and in the gulches where the ore is found, and a sufficient supply of water is also available. The distance to the railroad is about 100 miles at La Veta by the way of Sangre de Cristo Pass. Grain and hay are raised in the valley, and can be furnished at the mines at 2¼ cents per pound for oats and $15 per ton for hay.

EL DORADO MINING DISTRICT.

This was visited and reported upon by Mr. Niblack. This district lies between South Creston and Deadman's Creek, and is about 7 miles south of Creston district. It was organized in 1874, and a small town has been built which is called Sangre de Cristo Post Office. Two 5-stamp mills have been erected, but were not in operation when visited, October 29. The character of the ores is about the same as those of the first district, but the yield has not been sufficient to induce much expenditure in the development of the several prospecting shafts.

HARDSCRABBLE DISTRICT, ROSITA.

This district has been previously reported upon by Dr. Loew. Since his visit the Pocahontas, Humboldt, and Virginia mines have been worked continuously or nearly so, and the yield has been satisfactory, although it has hitherto been necessary to transport the greater part of the ore to Denver for milling. A new mill, in which the leaching process is used, was finished last December, and a 20-stamp mill was in process of erection. The estimated yield of the three mines mentioned was for 1875 $40,000, and for 1876 $200,000 The average yield of ore reduced was $110 per ton.

In conclusion, I wish to tender my thanks to the topographers, meteorologists, and recorder for their hearty co-operation and general attention to their duties throughout the season, thereby making it possible to complete the work assigned within the allotted time.

Very respectfully, your obedient servant,

ERIC BERGLAND,
First Lieutenant of Engineers.

Lieut. GEO. M. WHEELER,
Corps of Engineers, in charge.

APPENDIX B.

EXECUTIVE AND DESCRIPTIVE REPORT OF LIEUTENANT SAML. E. TILLMAN, CORPS OF ENGINEERS, ON THE OPERATIONS OF PARTY NO. 1, CALIFORNIA SECTION, FIELD SEASON OF 1876.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL SURVEYS WEST OF THE 100TH MERIDIAN,
Washington, D. C., April 15, 1877.

SIR: I have the honor to submit the following report upon the country visited by, and the operations of, Party I, California Division, of the expedition for surveys west of the one hundredth meridian during the field season of 1876. The area for work assigned by yourself to Party I falls in atlas-sheet 47, subdivisions "B" and "D" of the progress map, and is between the meridians distant from Greenwich 119° 48′ and 120° 38′, and the parallels of 39° 18′ and 40° 16′. It is situated immediately north of the portion of the Central Pacific Railroad between the stations of Reno on the east and Cisco on the west. The country to be traversed lay principally in the uplifted region which constitutes the Sierra Nevada Mountains. These mountains are here of considerable breadth, and at first sight give the impression of a confused mass, but a little observation shows that they are composed of nearly parallel ridges, the longer ones having to the northward a direction of about 25° west of north. The summit-line of the range is tortuous, correctly located, however, by the direction of drainage. To the east of this line the waters flow to the lakes and sinks of the Nevada basin. To the west they go to the Sacramento River, thence to the Pacific. The eastern wall of the Sierras crosses the Central Pacific Railroad at about the one hundred and twentieth meridian, which is here the boundary-line between California and Nevada. A single spur of the range projects to the east of this meridian and lies in Nevada. About 25 miles west of the eastern wall arises the second marked ridge of the Sierras, extending nearly parallel to the eastern, and forming here the western limit of our work.

The summit-lines of these ridges have received the local designation of eastern and western summits. The Central Pacific Railroad crosses the true summit-line of the Sierras upon the second of these ridges at about the meridian of 120° 20′. The summit-line, bearing as stated, remains upon this ridge for about 18 miles. It then makes nearly a right angle and crosses to the eastern wall of the Sierras. From this point, latitude 39° 36′, it runs nearly due north to parallel 39° 55′. It then has a direction nearly northwest to parallel 40° 16′, which was the most northern point visited by me. The axis of the second ridge changes direction at the point at which the summit-line leaves it, latitude 39° 29′, bearing nearly due north to parallel 39° 47′. At this parallel is found a second transverse ridge, immediately north of which the longitudinal ridges rise in closer proximity, all having the same trend as the eastern wall. For convenience of description, I have divided the area of my work, situated in the Sierras, into three sections, suggested by the configuration above noted. The southern section is the portion between the Central Pacific Railroad and the transverse divide upon which the summit-line crosses from west to east, and limited on the east and west by the two axial ridges before mentioned. The middle section lies between the same two axial ridges, north of the first and south of the second transverse divides. The northern section is north of the second transverse divide, extending west to meridian 120° 38′ and bounded upon the north and east by the summit-ridge of the Sierras, which here runs nearly northwest. In addition to the mountain area above located, Party I covered a narrow slip along the eastern base of the mountains extending from Reno to the parallel 40° 16′. Of the sections, already indicated, the southern is heavily timbered with pine and broken by long, broad, sloping spurs, usually from the west. The valleys or flats are of small extent and bear the names of the claimants. The waters of this section flow to the Nevada basin, passing the east wall of the mountains by the cañon of the Truckee River. Truckee and Boca are stations of the Central Pacific Railroad, situated in this section. There are several saw-mills from which lumber is carried to the railroad by flumes. These flumes are V-shaped troughs, supported upon trestle-work, extending from a lower to a higher level. At the higher level a stream of water is turned into the trough. This artificial channel then becomes the means for sending down enormous quantities of wood and lumber. Prosser Creek, in this section, has been dammed at the mouth and a pond formed, from which large quantities of ice are procured. Small herds of cattle and sheep are grazed in the flats during summer, but descend to lower altitudes in winter.

There are but few permanent settlers in this section away from the railroad and the mills. At the western side of this section, close on to the base of the second ridge, are nestled three beautiful bodies of water—Donner, Webber, and Independence Lakes. Donner Lake, the lowest of these, is about 5,800 feet above the sea; Independence Lake affords excellent fish. The middle section of my work is bounded by the two axial and two transverse ridges previously mentioned. It comprises an elevated valley of considerable extent, called Sierra Valley. This valley would approach in figure

a rectangular quadrilateral were it not that long-necked spurs project from the south and east, converting it into a right-angle triangle. This valley embraces about 140 square miles. At the southern vertex of the triangle is a little town, Sierraville; at the eastern, is Summit Post office. Between these two is Loyalton. At the northwest corner of the valley is Beckworth's Post office. The western and southern walls are heavily timbered with pine; the northern and eastern are partially bare. The valley is entirely taken up by settlers. At Sierraville, the head of the valley, the altitude is 4,880 feet. Near the head of the valley, vegetables, wheat, and even fruit can be grown with some success. Farther out from the timber and stream free radiation and accumulation of cold air at night prevent this. About three-fifths of the valley supplies good grass, from which large quantities of hay are secured for winter's needs. The meadows are situated along and near to the streams which flow along the north and west sides of the valley. The waters unite near Beckworth's Post office, to form the head of the Middle Fork of Feather River, passing to the west of the cañon of that stream. In the northern section the mountain ridges are nearer together, the valleys long and narrow, with a descending northwest trend. The valleys grow narrower with the descent, soon cañon, and empty their waters into Indian Creek, which here flows nearly west along parallel 40° 5'. Beyond this creek the spurs have a northeast direction to the eastern wall. No attempts are made to grow vegetables, fruits, or cereals in these valleys. A single day's ride, however, down the streams will take one to a region where fruits and vegetables can be grown with partial success. The difference of altitude between the points makes a marked difference, but other causes, easily understood, also facilitate such efforts. The heads of the valleys of this section are above the sea, on an average, about 5,500 feet. The wagon-road leading to Taylorville, which follows along the waters of one of these valleys, (Clover Valley,) descends 1,500 feet in the last three miles before reaching Indian Creek. There are claimants to all the grass-growing lands. Considerable herds of cattle are grazed here during the summer, but, as a rule, removed in winter. Only a few of the ranchmen remain here during the winter. This section, with exception of the small valleys, is well-timbered with pine. Common to the entire mountain area embraced above is the appearance of the surface-rock. It is all of volcanic origin. The entire area has once been flooded with melted rock. The transverse divide between the middle and northern section of my work is a mountain mass of solidified waves of lava, embracing beautiful specimens of the columnar structure. These rocks are generally of trachytic classes. In this region, and all others that I have ever visited where the surface-rock is of like nature, loose fragments are widely spread. Travel is always slow and tedious in such places. In order to account for this universal distribution of fragments, it is only necessary to suppose that surfaces resulting from volcanic action were usually uneven, with sudden ascents and descents from one level to another. The continued action of gravity and the weather would then accomplish what we now see. In places, the surface-rock is cut through by cañons, and the primary formations displayed. I can give no definite information as to the rain-fall in this region. Numerous statements were received upon this point, but the discordancy was correspondingly great. The amount of rain is not, probably, over 12.1 inches. The daily range of temperature was usually very great. On the 19th of September, at a camp on the northern section, at night, the minimum thermometer recorded 19°; the same day the maximum was 77° in the shade, and 112° in the sun; the maximum difference between the wet and dry bulbs for the same day was 20°. During the season, the wet and dry bulbs differed by from 6° to 20°. In the northern section there is usually 6 to 10 feet of snow during the winter, (this not included in the estimated rain-fall.) The inhabitants who attempt to remain at their ranches during winter use snow-shoes from 8 to 12 feet long, and are confined to very limited journeys from December to April. In Sierra Valley and the flats of the southern section the snow-fall is considerably less. The streams of the entire region abound in fish—in the northern sections the brooks are almost alive with mountain-trout. In this section, too, frequent indications of deer were seen, but not so in the middle and southern sections. In addition to the mountain areas described above, party 1 covered a small stretch of country east of the Sierras, extending from Reno along the eastern base of the mountains to the most northern parallel visited. To the east of the Sierras the axes of the ridges lie more nearly north and south. The valleys between them are deserts of sand and sage-brush. A narrow slip of land close in to the eastern wall of the Sierras furnishes good grazing, and is occupied by settlers. The growth of timber ceases entirely at the eastern base of the Sierras.

The routes of communication traversing the region of our work may be briefly stated as follows: From Reno, which is the most eastern point, a road leads nearly directly west across the eastern wall into the southern section. It then divides; one branch continues nearly due west across the second ridge; the other branch turns to the south, and runs near to and parallel with the railroad, crossing the summit-line of the Sierras at the same point. Another road leads from Reno along the eastern base of the mountains to Susanville, beyond the limits of my work. A branch from the road

crosses through Beckworth's Pass to Summit Post Office, at the eastern vertex of Sierra Valley, and continues along the northern side of the valley, passing out along the middle fork of Feather River. From Beckworth's Pass there is a road along the eastern side of the valley, through Loyalton, to Sierraville, which then passes westward across the second ridge. Still another road passes from Reno direct to Loyalton. Three roads lead from the southern into the middle section, and one from the middle to the northern. From the northern section there are three roads crossing east to the Reno and Susanville road. Beckworth's Pass is 5,200 feet above the sea level, about 1,800 feet below the summit-pass of the Central Pacific Railroad. I had intended to include herein a profile of the road to Beckworth's Pass, with grade per mile, but I find the hypsometric observations for that day too unreliable for my purpose.

I shall now proceed to state the movements of the party. The California division of the survey was organized at Carson City, Nev. I was placed in charge of this division of the survey, but your own arrival at an early day at the rendezvous-camp renders reference to any other party than my own unnecessary. I was placed in immediate command of party 1, which consisted of the following members: Myself, as executive officer and field-astronomer; Mr. Gilbert Thompson, triangulator and chief topographer; Mr. F. M. Lee, meteorologist; Mr. William Looram, odometer-recorder; Mr. E. D. Miner, assistant topographer; 2 packers, 1 cook, 1 laborer. A six-mule wagon and driver were placed at my disposal for a few days; 9 riding and 11 pack mules were allowed the party. The instruments supplied were the same as usual during the past two years, except that an attempt had been made to employ a kind of combined transit and theodolite, to be used as an astronomical instrument as well as for triangulation. The rough usage to which such an instrument is subjected in triangulating, and the unfavorable circumstances under which astronomical observations are often unavoidably attempted, combine to condemn the instrument for such double use. Two topographical transits (Young's) were allowed; one, I believe, has before been the allowance.

The party left the rendezvous-camp at Carson City on September 6 for the field of operations, proceeding direct to Reno, meandering and profiling the route. The rations of this party had been accumulated at Reno. Owing to the late beginning of work and the probability of early snow in my area, I decided to work in the northern section first. The party reached Reno on the 7th. I concluded to leave Reno with forty days' rations, and at the end of that time I expected to be able to return without material loss of time. On the 8th I left Reno with the wagon, carrying 32 days' rations and 1,000 pounds of barley. Mr. Thompson was left in charge of the pack-train with 8 days' rations, to follow my trail as rapidly as the regular work would allow. I followed the road along the east base of the mountains, crossing through Beckworth's Pass into Sierra Valley, continued west to Beckworth's Post Office. At this point I passed from the middle to the northern section by the road connecting them. At the head of Clover Valley, one of the small valleys of this section, I was enabled to leave my rations and forage in the custody of a ranchman. I then retraced my course. On the 11th September I met the train, having just entered Sierra Valley. The wagon and driver were then dispatched to Carson City. Mr. Thompson had already occupied one triangulation-station, Peavine Mountain, which is northwest of Reno and east of the Sierras. Two others were made on the main ridge of the Sierras, respectively, on the 12th and 13th. In addition to this, several topographical stations were made before reaching the ration-station in Clover Valley, which was on the 15th September. From this camp we worked to great advantage for 15 days. Parties were sent out in all directions, returning by different routes when practicable. The same animals were not used continuously, which is great economy. On the 1st October the party left the camp. Our packs were now much lighter, rations having been considerably reduced. We proceeded farther north than we had yet been, to the extreme triangulation-point in that direction, which is situated in latitude 40° 16′. At this point the party passed to the east of the Sierras, striking the Susanville road near the northern-shore line of Honey Lake. This lake receives the drainage of the eastern slopes of the Sierras for 50 miles, both north and south. It is about 12 miles wide and 15 long, not over 5 feet deep on an average. Myriads of ducks and geese were seen there. Turning to the south, the party kept the road to the point from which we previously left it, crossed a second time through Beckworth's Pass, followed down the east side of the valley, then up the west to Beckworth's Post Office, then diagonally across the valley to Loyalton, and from there to Reno, reaching the latter October 16. From September 6 to October 16, inclusive, every day had been available for work. Bad weather kept the party in Reno during the 17th. The wagon returned to me at this time, as had been previously arranged. An enlisted man was teamster, and a corporal was in charge of the wagon. One of my packers left me here, but I did not employ another, as the wagon more than replaced him. On October 18 the party left Reno by the only unmeandered road which led to our field of work. It was called the Hennes Pass Road. By it we crossed into the southern section of our work, and continued along the northern side of it. On the 20th another camp was established, with intention of remaining thereat for some time.

From this camp Mr. Thompson was sent to occupy the most western of the triangulation-points. While Mr. Thompson was gone upon this trip I attached an odometer to the wagon, and meandered one of the roads leading into Sierra Valley and returned by a second. Mr. Thompson returned to camp on the 25th. It rained steadily during the 26th and 27th. On the night of the 27th about five inches of snow fell at our camp, and much more in the mountains. The weather permitted no outdoor work on the 28th and 29th. On the 30th of October our camp was moved to within 4 miles of Truckee, as more snow was anticipated. On November 1 the weather promised better, and I started with Mr. Thompson to occupy the last triangulation-station deemed necessary for covering my area. This point was Castle Peak, situated a few miles north of Summit Station of the Central Pacific Railroad. The ascent of this peak was extremely difficult. The snow in the mountains averaged about 18 inches; in many places it was from 2 to 4 feet deep. After the most intense and continued exertion, attended with no little danger, we reached the top late in the afternoon of the 2d November. On the 3d I returned to camp near Truckee. On November 4 and 5 the weather was bad. I learned at this time that Mount Rose, a high point south of the railroad, had not been occupied, the intention of the party operating in that area to do so having been interfered with by bad weather. This point being very essential, I started on November 6 to make the ascent. On account of the snow it was very difficult, but we reached the top on the 7th; returned to camp on the 8th. On the 10th November I dispatched the party to Carson City, going myself, by rail, to Virginia City, to ascertain whether connection with the base, measured near that place, could be made from the work done. Returning to Carson City on the 12th, I found the pack-train arrived. I deemed it advisable to reascend Mount Rose, and accordingly set out for that point on the 13th. The ascent was made on the 14th. The party continued topographical work in the vicinity until the 22d November, when they returned to Carson City and disbanded. During the season the system of work previously adopted in the survey was followed. The system and its advantages have been ably stated by Lieutenant Marshall in his report of 1876. During the season, 13 triangulation-stations were occupied and 46 topographical three-point stations; numerous meander-stations, which can be checked by same method; several points were located by intersections; 1,040 meander-stations were made, each of which was also an aneroid-station; 94 separate cistern-barometer stations were made; 625 miles of travel were meandered; 515 miles traveled without meander. Hypsometric and meteorological observations were made in exact accordance with printed instructions from this office, and my experience enables me to suggest no alterations in said instructions. Of the area visited by this party, approximately $\frac{2}{10}$ is good grazing, $\frac{1}{10}$ barren, and $\frac{7}{10}$ good timber-land. The only mines are located near Peavine Mountain, and were not visited by me. It will be observed that I have given only a general description of the country; but, as the region is of no unusual interest, I deem it sufficient. Any description which would render intelligible the detailed movements of a party in an unknown region would require more time and labor than the information would warrant, since the results will finally appear upon the map. I have therefore only indicated the movements of the main portion of the party.

In conclusion, I cannot recommend too highly the following of my assistants: Mr. G. Thompson, chief topographer; Mr. F. M. Lee, meteorologist, and Mr. William Looram, odometer-recorder. Mr. Thompson has had much experience, and it can be truthfully said that he is untiring in his efforts, and his zeal appears ever to increase. Mr. Lee's familiarity with his duties and interest therein left me little responsibility in that work. Mr. Looram, in addition to the monotonous and wearing duty of odometer-recorder, was ever ready and capable to assist in meteorological observations when necessary. The movements of a party in a field are greatly facilitated by a good packer, and I yield a grateful acknowledgment to my chief packer, Mr. C. H. Howell, as the best I have ever known. His intelligence saved me much anxiety, and his excellent care of the animals was a great practical aid to the expedition.

Very respectfully, your obedient servant,

S. E. TILLMAN,
First Lieut. Corps of Engineers.

Lieut. G. M. WHEELER,
Corps of Engineers, in charge.

APPENDIX C.

EXECUTIVE AND DESCRIPTIVE REPORT OF LIEUTENANT THOMAS W. SYMONS, CORPS OF ENGINEERS, ON THE OPERATIONS OF PARTY NO. 3, CALIFORNIA SECTION, FIELD SEASON OF 1876.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL SURVEYS WEST OF THE 100TH MERIDIAN,
Washington, D. C., April 15, 1877.

SIR: I have the honor to submt herewith the executive report of Party No. 3, California section of the survey, for the field season of 1876, together with a brief report on the mining interests of the Comstock lode.

EXECUTIVE REPORT.

The duties assigned to the party under my charge were to lay out and measure a base-line, and develop it for the use of the outlying parties in the vicinity, and after this was done to commence work on a detailed map of the country embraced by the mining interests of Virginia City, Nev., and the neighboring district.

I arrived in Carson City, Nev., August 23, 1876, and after making the necessary preparations and procuring supplies, laborers, instruments, &c., started by wagon, August 28, for the valley of the Carson River, near Sutro, whither Dr. Kampf and Mr. Karl had preceded me to select a place for the base-line. On arriving in the valley camp was made on the banks of the Carson River, and as it was to be permanent for some time, we made it as comfortable as possible. The base-line was laid out on a very straight portion of the old emigrant road through the valley, and the work of development immediately commenced. On the 4th of September the party was joined by Mr. Louis Seckels, and on the 10th of the same month by James Bullock and an ambulance and team.

The party now consisted of Second Lieut. Thomas W. Symons, Corps of Engineers, executive officer and field astronomer; Dr. F. Kampf, astronomer; Mr. Anton Karl, topographer; Mr. Louis Seckels, meteorological observer; Mr. Simon B. Cameron, aneroid and odometer recorder; James Bullock, teamster, and John Rafferty, cook.

The base development being finished, the party separated, Dr. Kampf remaining at Sutro to measure the base. In this he was assisted by Mr. Seckels and three hired laborers. The apparatus used in the measurement is the invention of Dr. Kampf, and consisted of a wooden rod with finely-graduated scales at both ends, and at the center an apparatus for determining its deviation from the horizontal, and three iron stands with nickel tops, on each of which was engraven a fine line, this line being the initial point of each successive measurement with the rod. Comparisons of the rod were made every morning and evening with the standard rods of the United States Coast Survey, and the reading of the rod corrected for temperature. A full account of the apparatus, the mode of its use, and the results obtained, will be found in the report of Dr. Kampf.

On September 16 I went to Virginia City, with Mr. Karl as topographer and Mr. Cameron as meteorological observer, and the necessary laborers, and commenced work on a detailed contour map of the city and vicinity. This work was done with the plane-table, and the method pursued was the following: A number of points were selected whose projections would occupy different points on the plane-table sheet, and these were occupied with the transit, and their positions carefully computed in reference to the base and the monument points used in its development. These points then being laid down on the plane-table formed the foundation for the detailed work, which was done by Mr. Karl. Other points were occupied with the transit during the time that the sheet was being filled in, and these, together with cross-sight stations, being computed, formed checks which were continually applied to the plane-table work. At each of the points occupied by the plane-table, and at many others, as hills, ravines, cañons, road-crossings, saddles, mesas, &c., barometric observations were taken for altitude, which, being referred to synchronous observations taken in camp under the same natural existing circumstances of atmospheric pressure, temperature, and humidity, gave very accurate relative altitudes, and the altitude of the camp, being determined by a long series of observations, enabled us to determine the elevations of all the points above mentioned above the sea-level very accurately. Besides the barometric readings, elevations to well-determined points were read from the vertical limb of the transit and from the alidade of the plane-table, and level-lines run with the Y-level. From these data the contours are being put in in the office of the survey at Washington.

The constant aim has been to secure the greatest accuracy and to leave no natural feature of the surface or work of any importance unrepresented, and Mr. Karl, for his intelligent devotion to the work and his care and accuracy, deserves the greatest credit.

Three plane-table sheets were filled in, two to a scale of 1,000 feet to an inch, and one to a scale of 500 feet to an inch, the larger scale being used in delineating that portion of the country including Virginia City. The country gone over includes Virginia City and the northern portion of the Comstock lode, the country to the north and west

traversed by the Geiger grade, and that to the east embracing the basin between Mounts Emma and Davidson.

Dr. Kampf, after finishing the base measurement, went to Virginia City and determined the azimuth of the triangulation lines from the astronomical monument, and on October 23 started for Washington. Mr. Seckels joined the party in Virginia City and devoted himself with assiduity and intelligence to the necessary meteorological work. November 20, I received orders to proceed to Carson City to disband for the season, where I arrived November 23. After spending two weeks in Carson, seeing to the storage and shipment of public property, taking inventories, and acting as member of a board of survey, I started for Washington on the 5th of December. In obedience to verbal orders from Lieut. S. E. Tillman, in charge of disbanding the California section of the survey, I stopped at Ogden, Utah, and made an inspection of the Government observatory there, and an inventory of all the public property pertaining to the expedition, the reports of which have been submitted to Lieutenant Wheeler.

On my arrival in Washington I was placed in charge of the meteorological records and computations, and also to supervise the compilation and reduction of the plane-table work. I have carefully recomputed all the positions used in the field and several others, which will give the foundation for the work when it is next taken up in the field.

DESCRIPTIVE REPORT.

The area embraced in the contemplated and partly constructed detailed contour map is 12¾ miles long from north to south and 9½ miles broad from east to west, and contains within its limits the richest mines of silver and gold of which the world of to-day has any knowledge. About 12 miles to the east of the summits of the Sierra Nevada Mountains, a little northeast of Lake Tahoe, in the midst of piled-up masses of volcanic rocks of all kinds, where during the summer rain never falls, and where nothing grows but sage-brush; where the mind of man can imagine nothing to add to the scene to make it one of more cheerless grandeur and desolation, is situated the famed Comstock lode. Above the lode and its branches have been built the towns of Virginia, Gold Hill, Silver City, and American Flat, in which are situated the upper works of the mines and their many adjuncts. Immediately connected with it by virtue of their ore mills are the towns of Dayton and Empire, and from being the outlet of the Sutro Tunnel is the town of Sutro. I shall not attempt to describe these places in detail, but shall simply note some observations of my own and some of the changes which have taken place since other reports have been written, and which are continually taking place.

At the time when Mr. Clarence King wrote his report upon the geology of the Comstock, it was considered that the portion of the lode between the Gould and Curry, and the north line of the Central, corresponding to the south side of the Ophir, was unproductive, and from the apparent closing in of the walls it was supposed that it never would develop into anything of much value. Since then, however, under the names of the Consolidated Virginia and California, this region has developed the Big Bonanza mines, one, the Consolidated Virginia, yielding in the year 1875 alone the enormous amount of $16,731,653.43 from 169,095 tons of ore. This is a gigantic illustration of the fact that the vein is very unreliable, and that it is not safe to place very much reliance on analogical reasoning with regard to it.

The old controversy as to there being a single vein of which the outlying ones are branches or spurs is still unsettled, but agencies are at work now which will, in all probability, settle the question at law in a few years at the farthest; these agencies being particularly the Sutro Tunnel, the Mint Mine, and the Great Combination shaft.

In the report of Mr. King the Comstock lode is supposed to extend approximately north and south from the vicinity of the Utah Mine, to the mines in and about American Flat, and no mention is made of a branch lode extending down Gold Cañon. It is generally conceived now that the great lode branches near the head of Gold Cañon, and one branch extends southwestward toward and beyond the Rock Island Mine in American Flat, and the other extends southeastward down the cañon. Some of the most promising and productive mines of all the region are situated in this latter branch, notably the Overman and the Justice, which have both big bonanzas, the latter especially working some very rich ore, of which a specimen now in this office assays approximately $12,000 per ton.

Prospecting and exploitation are still going on in a great many places, both on the lode and off it, and the horizontal limits of pay-ground is not yet reached, or at least is far from being determined. But many things would go to show that the vertical limit of successful working has been reached in some of the mines as long as the present system prevails. In the Savage Mine, nearly or quite a year ago, as a drift was being pushed to the east at a depth of 2,300 feet, a heavy volume of hot water was encountered which drove the workmen back and up the shaft, and, in spite of the pumps, continued to come in until it reached the 1,900-foot level. Since its first influx larger and more powerful pumps have been put in and kept at work continuously except for accidental stoppages, and at last accounts the water was still at about the same level. Although at times the pumps would gain on the water, the water would in a short

time assert its supremacy and come back to its accustomed level. It also flooded a neighboring mine, the Hale and Norcross, which has also been at work pumping ever since, and thus these two mines are unable to proceed with any profitable work or work of exploration, while there is still an enormous drain on the pockets of the stockholders for the expenses of pumping and the other expenses incidental to the flooding of the mine.

Heretofore all the large bodies of water struck in the mines have been at a higher level and have been rapidly pumped out and have not returned in large quantity, and this has strengthened the idea that the water occurs in pockets or reservoirs, and that when these are drained off it will cause no further trouble. This water in the Savage Mine, however, seems to tell a different story. It is very hot, about 154° to 160° F., and in all probability comes from the same heated source as the water which wells up from the Hot Springs in the valley below at Steamboat. As these springs are constant, it is altogether probable that the water which enters the Savage is also constant or nearly so, and that it connects with the heated water which permeates in a more or less connected manner all the fissures and subterranean channels below. In one mine which I visited, the Imperial and Empire, I descended to a depth of 2,135 feet and found the temperature to range from 110° to 115° F. There was at least one stream of hot water coming into the mine, which, on testing, I found to be 154° F. In other parts of the world, where mines have been sunk very deep, it has been found that on an average the temperature increases 1° F. for every 50 to 60 feet of descent from the depth at which the temperature first becomes constant, which is about 100 feet below the surface; this constant temperature being, as near as it can be determined, 47° F. Assuming 55 feet to be the equivalent in descent of 1° F., we have in the Imperial and Empire

$$\frac{2135^{\text{ft.}} - 100^{\text{ft.}}}{55^{\text{ft.}}} + 47^\circ \text{ F.} = 84^\circ \text{ F.}$$

or, according to this rule, the temperature at the depth of 2,135 feet should be 84°. Instead of this, and in spite of the fact that great quantities of cold air are pumped in, it reaches in places as high as 110° and 115° F. Undoubtedly the cause of this great heat is the inpouring and circulating hot water, which comes in quite large quantities, the amount pumped from the mine being about 6 miner's inches. There are two hypotheses to account for this heated water: one being that it is heated by the chemical action going on in some mineral or other vein through which it passes. It is asserted and believed by many that as the hot Savage water came in from the east, when the exploration shall be pushed on eastward a vein of the same general character as the Comstock will be struck, the chemical action in which is the cause of the heating of the water. The supposition that such a vein exists is no doubt very materially strengthened by the existence of this hot-water stream, but it can scarcely be considered as proof. The other hypothesis, and to my mind the more plausible one, is that the water comes up from the heated interior of the earth. The water which falls to the earth in the form of rain and snow, and which penetrates below the surface, exists in many conditions throughout the crust of the earth, sometimes occurring in pockets, which are filled slowly by infiltration or narrow inlets, but which on being struck empty themselves quickly and are no further cause of trouble; sometimes in large fissures through which the water is continually circulating, and which, on being struck, give an almost unintermitted stream for months and years. Such a fissure exists in the Sutro Tunnel, and it is observed that when such a fissure-vein of water is encountered, it diminishes its yield for some time until it reaches a point when it becomes constant. This may be accounted for on the supposition of connecting pockets, which are gradually drained off. This water finally finds its way down to the heated interior of the earth and is there converted into steam, which in its efforts to rise forces back the water, and thus an equilibrium is attained, the water and fire making the steam and the steam holding the water in suspension. The steam in its efforts to escape percolates up through the water and heats it, and this in turn heats the surrounding rocks, and possibly is the cause, not the effect, of the chemical action which is continually going on in the mineral veins. When this hot water and steam can find a direct outlet to the surface, they appear in the form of hot springs and geysers; when they cannot, they give up their heat to the rocks and the down-pouring cold surface-water. There is no doubt that the mine in which this water occurs is debarred from further downward progress if the water remains constant, unless some new method of drainage is found and adopted; for if it were possible to keep it down by a great addition to the pumping force, it would cost so much that the mine would be totally unprofitable. What this new method of drainage will be remains to be seen. Possibly it may be the Sutro Tunnel.

The tunnel has now reached a length of between 15,000 and 16,000 feet, and is being pushed forward with marvelous celerity, making on an average 300 feet per month in length. It will, when it reaches its entire length, (which it will probably do in the spring of 1879,) strike the Comstock, near the Savage, at a depth below the surface of about 1,900 feet, and then the water which may impede the working of the mine will have to be pumped a vertical distance of 1,900 feet less than now. It is altogether

possible that, with the present engine-force, which now makes no permanent headway against the water, the water may be raised to the tunnel-level and run off through it to the Carson River. At any rate, it will very much facilitate the keeping down of the water and will afford a new foundation 1,900 feet below the surface from which to work As with the Savage, so with the other mines which are much troubled with water; when the tunnel or one of its branches reaches them, it will take off the water which comes in above the tunnel-level, and will lessen very much the work of pumping out that which comes in below. It will also greatly assist in ventilation ; but in regard to its merits in this respect I am unable to speak.

As regards the feasibility of using the tunnel for the extraction of ore, it admits of discussion, and can only be decided when the time comes. The ore now, after being hoisted, is taken from the shaft, and in some instances, as the Bonanza Mines, is milled very near the mine; in others, it is hauled in wagons to various distances from one to three or four miles, and in others still it is taken by the railroad to the mills along the Carson a distance of from 12 to 15 miles. If the ore when taken from the tunnel-mouth should be conveyed to the present existing mills and reduced, it would unquestionably be more expensive than now; but if new mills should be built near the tunnel-mouth and run by the tunnel-water, or built on the banks of the Carson River, just below, in my opinion the ore could be reduced at a much lower cost than at present, and the ore which now is too poor to work or which barely pays for milling might be made to pay a good profit. The capacity of the tunnel of course would be limited; but with a double track, and care and economy in its service, it would probably meet all the demands upon it.

Situated, as the Comstock is, in the midst of a dry, totally-unproductive desert, over 6,000 feet above sea-level, on the side of a mountain, needing and using vast quantities of supplies of various kinds, it may not be wholly uninteresting or uninstructive to inquire as to the nature and source of these supplies, and the methods of getting them to their destination.

One of the first wants felt by the pioneers of the Comstock was water, and it was procured in very limited quantities from a few springs in the vicinity. As the lode became more and more developed, the mines and mills and the gathering people demanded more and more water, and the want of it was severely felt. The mills sunk shafts and drifted for water, and a good deal was obtained from the tunnels driven into the mountains in search of the precious metals. A company was finally formed for the purpose of gathering and furnishing water, and their supply was chiefly obtained from the prospecting tunnels and conducted in pipes about Virginia City and Gold Hill. But the supply was still far from sufficient and the quality very bad, and the company finally achieved a great triumph in hydraulic engineering by bringing to the cities of the Comstock an abundant supply of fresh and clear mountain water from the summit streams and lakes of the Sierras. The water is now taken from Dall's Creek, in the Sierras, but the company are extending their flume to tap Marlette's Lake, from whence nearly all the water will be taken. This lake is 1,600 feet above Virginia City and within a mile of Lake Tahoe. The water will be conducted in a wooden flume in a northerly direction for about 5 miles, then, passing under the mountains through a tunnel nearly a mile long, it pursues its winding way in a flume for 6 miles, when it reaches the point where it becomes necessary to make the descent into the Washoe Valley below. There it is received into a double line of iron pipes, which conduct it down to and across the valley and up the opposite mountain. The pipes are, one. 12 inches in diameter and riveted with $\frac{5}{8}$-inch bolts. It is $\frac{5}{16}$-inch thick at the lowest point, where the pressure is greatest, and tapers from this point to the entrance and exit, where it is only $\frac{1}{16}$-inch thick. The other is a 10-inch pipe, lap-welded, and of uniform thickness. From the point of entering the pipe the water makes a descent of 1,963 feet in a horizontal distance of $1\frac{1}{4}$ miles into Washoe Valley. There it commences to ascend until it reaches a point 1,498 feet above the lowest point, at a distance of 6 miles from it. Here it is again received into a flume, and is conducted circling about the mountain-slopes a distance of about 8 miles, until it reaches its destination. The flume has a fall of 1 foot to each 44 feet horizontal distance. The amount supplied now is about 3,000,000 gallons daily, but its capacity, when fully completed, will be more than 10,000,000 gallons daily.

The mines and mills devour a vast amount of fuel and lumber. In that volcano-formed land there is no coal, and the fires must be fed with wood. All the wood which grew about the Comstock was used up long ago, and now, as before in the case of water, it is the Sierras which furnish the supply. This is taken from the great basin about Lake Tahoe, and from the eastern summits above Huffaker's, and is brought down the mountains in flumes, which are gradually extended backward as the supply is exhausted. There are saw-mills on the mountains at which is cut the square timber and the lumber used in the mines and in the cities. The flumes are so constructed that timber 40 feet long can be sent down. The wood and lumber when it reaches the valley is mostly taken by the Virginia and Truckee Railroad, and conveyed to the places where it is to be used. Immense quantities of wood are also floated down the Carson River to Empire, Dayton, and Sutro, and it is estimated that at least 250,000 cords of wood

are annually used by the Comstock and its co-operating industries. This immense amount of wood may be better conceived of when we remember that if it should be piled up 8 feet high it would cover an area of 100 acres. The square timber is used in great quantities in the mines, in the construction of galleries, shafts, inclines, &c., and in stoping.

The fertile plains and hill-sides of California furnish the subsistence for the men and women of the Comstock, and for their horses, mules, and cattle; and the manufactories of the Pacific coast provide most of the machinery for the mines and mills, although some comes from the far-off Eastern States.

As everywhere on the Pacific side of the Rocky Mountains, there are great numbers of Chinamen about the Comstock. They are not allowed to be employed in the mines or mills, or in any of the work connected therewith, being prevented by the miners' union. They find employment as laundry-men, as household servants, as peddlers of vegetables, and as gatherers of garbage and wood. The wood business is a fine illustration of how a thrifty race can make money out of the most unpromising materials. A Chinaman gets a donkey and a pack-saddle, and spends all his time during the summer going out on the hills and grubbing up the stumps and roots of the fir and pine trees which were long ago cut down. When he gets as much as his donkey can carry, he loads him up and drives him back to the place where he has his wood-pile. It is a picturesque, but not a pleasant, sight to see a dirty Chinaman driving an overloaded donkey, possibly lame and trembling with pain and exhaustion, along some lonely road. In the winter, when the snow is on the ground and the roads are impassable in the country, John loads up his donkey with the smallest amount of wood which will make a respectable showing, and travels about the streets in search of some one who wants his load of wood more than they want a dollar. The Chinamen have never succeeded in making friends of the white men, and I cannot but think that the cause lies in their utter inoffensiveness. They will submit tamely to all kinds of neglect, contempt, and abuse, and this only begets the feeling in the mind of the strong, hearty, world-buffeting American or European that they are unworthy of any consideration. In the land of fighting-men, they are the non-fighters, the cringing class; and as long as they are so, they will be treated in the same manner as at present.

All the supplies, machinery, wood, lumber, &c., are brought to the market by the Virginia and Truckee Railroad, which is itself a wonder in that land of wonders. It was first completed from Virginia to Carson in the winter of 1869 and 1870, and has since been extended to connect with the Central Pacific at Reno. It is an immense auxiliary to the mining interests of Nevada, as we see when we consider the vast amount of freight of all kinds carried and the great use it is in transporting ore to the mills.

There are at the present time about fifty mines being worked or prospected on the Comstock and its branches, but of this number there are only five or six which pay expenses; all the rest are working on assessments. There are about 400 incorporations on the Comstock, employing a nominal capital of $3,000,000,000. This would be the actual value of the mines incorporated with the stock at par. Their values, at the ruling prices of June 1, 1876, according to the San Francisco Stock and Exchange Board, was $163,580,000.

The following table, taken from the report of the State assessor for the quarter ending September 30, 1876, will give an idea of the condition of the principal mines:

Abstract statement from the quarterly assessment-roll of the proceeds of the mines of Storey County, Nevada, for the quarter ending September 30, 1876.

Name.	Tons of ore extracted.	Value per ton.	Gross yield or value.	Actual cost of extraction.	Actual cost of reduction or sale.	Total cost.	Net yield or value on which taxes are levied.	Total amount of tax.
Belcher*	30,936	$18	$566,976.10	$216,552.00	$351,866.00	$568,418.00	$113,395.22	$2,778.18
California	53,061	97	5,156,026.84	354,881.48	742,643.70	1,445,468.43	3,710,558.41	72,355.89
Consolidated Virginia. †	15,660	97	1,533,308.64	315,850.05	191,660.30	1,145,036.64	613,323.45	11,959.81
Chollar-Potosi*	6,720	19	129,998.47	142,167.83	74,860.00	217,027.83	25,999.69	506.99
Crown Point*	4,783	13	65,676.35	....	....	170,000.53	13,135.27	321.81
Imperial	1,515	62	94,857.06	15,153.50	18,180.00	33,333.50	61,523.56	1,507.33
Justice †	6,911	31	214,971.36	62,203.50	76,025.50	141,684.50	85,988.54	2,106.62
Ophir †	27,358	25	969,096.72	273,585.00	328,302.00	601,887.00	387,638.69	7,558.95
Overman*	439	25	11,393.46	17,560.00	5,278.44	22,838.44	2,278.69	55.83
Total	......	....	7,742,305.00	....	....	4,345,794.87	5,013,841.52	99,335.10

* 80 per cent. deducted by law and exempt from taxation.
† 60 per cent. deducted by law and exempt from taxation.

It will be seen from an examination of the table that the only mines which have a paying record are the California, Consolidated Virginia, Imperial, Justice, and Ophir

The climate about Virginia City is wonderfully fine for the health and spirits of human beings. All through the summer it very seldom rains, and the meteorological records show an almost unbroken succession of cloudless, warm days and cool, delightful nights. The dryness of the atmosphere makes the heat very easy to bear, as long as the system has enough liquid to evaporate freely. The thermometer had a range very often of from 35° to 50° in the shade in a single day. One day I tested the sand on the plain below Sutro, and found it to be heated by the sun's rays to 135° F. That same night the thermometer went down to 44° F.

I wish to express my thanks to every member of my party for their unceasing and cheerful co-operation, and to the citizens of Virginia and the neighboring towns for their uniform courtesy and kindness, and their readiness to aid us by every means in their power.

Very respectfully,

THOMAS W. SYMONS,
Second Lieutenant of Engineers.

Lieut. GEO. M. WHEELER,
Corps of Engineers, in charge.

APPENDIX D.

EXECUTIVE AND DESCRIPTIVE REPORT OF LIEUTENANT R. BIRNIE, JR., THIRTEENTH INFANTRY, ON THE OPERATIONS OF PARTY NO. 4, CALIFORNIA SECTION, FIELD SEASON OF 1876.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL SURVEYS WEST OF THE 100TH MERIDIAN,
Washington, D. C., April 15, 1877.

SIR: I have the honor to submit the following report of the operations of Party No. 4, California Section, of the survey for the field season of 1876.

The party was organized at Carson on the 1st of September; Lieut. R. Birnie, executive officer; J. C. Spiller, topographer; W. A. Cowles, meteorological recorder; S. F. Wood, odometer recorder; Benjamin P. French, packer; Joseph Easten, assistant packer; George Willig, cook; Private Peter D. Niver, Company D, Twelfth Infantry.

We were provided with one 10-inch and one 20-inch triangulation instrument, (Würdemann's,) two small theodolites, (Young & Sons,) pocket-compasses, two cistern and three aneroid barometers, (Green,) and wet and dry bulb and maximum and minimum thermometers; the meterological instruments having all been compared with standards, and a final comparison of the barometers made just before leaving Carson. Rations for twenty-five days were taken here, which, with instruments, bedding, &c., made a little more than 220 pounds per mule for the ten pack-mules. The number of riding-mules was eight; we had also one extra mule and one bell-mare.

I was instructed to complete with the party the surveys of Atlas-sheets 48 C and D, a previous expedition under this survey having passed through the eastern portion of 48 D, and Clarence King's survey of the fortieth parallel having embraced about two-fifths of the area of the sheets, along the north line, thus leaving us a belt of country running east and west about 116 miles, and north and south 36 miles, Austin, Nev., being in the northeast corner of the area. It was found necessary, however, to extend our routes considerably beyond these limits, for the purpose of carrying on the triangulation, and in these cases topographical notes were taken as well. Fremont in 1844 and 1845, and more particularly Simpson in 1859, had partially explored this country.

DESCRIPTION OF THE ROUTE.

We left Carson City September 5, and, passing through Empire and Dayton, made our first camp, with the party of Lieutenant Symons, on the north bank of the Carson, a few miles below Dayton. The following day Mr. Spiller and myself climbed a peak about 8 miles to the north of this camp, to determine, if possible, something of the mountainous character of the country we were about to enter; but the point proved too low, and a topographical station was made. It was deemed necessary to occupy Mount Lyon, the highest peak in the vicinity, in order to connect our triangulation with the base being measured and developed by Lieutenant Symons's party.

At Camp No. 1 the party was divided. Mr. Cowles, with the pack-train, proceeded down the Carson to Buckland's ranch, one day's march, meandering the route close along the north bank of the river, passing ranches at intervals along the river, and the

site of Old Fort Churchill. This was abandoned several years since; the adobe buildings are still standing in part, but the wood-work has been all removed.

The remainder of our party forded the Carson at the camp, and, passing by the west of Mount Raw, a few miles from the river came upon and followed the still excellent road that leads from Dayton to the old mining town of Como. This place, now entirely deserted, is situated at the summit and in the first saddle of the Como range, south of Mount Raw. In 1863 it was a flourishing town, and we were told two daily lines of stages were running between the town and Dayton. The mines proved unremunerative, and it was soon abandoned, the remains of two or three houses now alone remaining. Wood in small quantities is hauled from the vicinity to Virginia City. There are two springs, one on each side of the divide, and about a mile from the summit. Several more springs were found along the eastern slope of Mount Lyon, being about the head of Churchill Cañon, that runs to east from the range, and then turns north into the Carson; water flows only in the upper part of the cañon.

Mount Lyon was occupied September 8, and proved a most valuable station. This is the highest peak in the Como range, and is distinctly visible from Carson City, from which it is about 16 miles distant, and bears nearly due east. Mount Raw is in the same range, 5 miles to the north. Every prominent point afterward occupied was visible from Lyon. The Toyabe range to the east, 125 miles distant, the limit of our area in that direction, formed the horizon. Irregular low broken, and barren hills and desert flats seemed to extend to the great flat of the Humboldt, and Carson sink and lake; the Carson River, winding eastwardly through these, was marked by a line of cottonwood trees; and to the southeast, some 20 miles distant, appeared the north bend of the Walker River, where, according to report, (except in Reese River Valley, away to the eastward,) we would find the only agricultural settlements, or country worth the farmer's toil. The rest was pictured as very barren indeed.

Just beyond the great flat appeared the Sand Spring range, running north and south. The range is much depressed about the Sand Spring Pass, and this depression continues to the next range, (although the two are separated by the Fairview Valley;) there it is the wash flowing westwardly, through Middle and West Gate, into Fairview Valley that cuts the range through and leaves no summit to surmount. The Fairview Peaks rise abruptly on the south side of the wash; while on the north several parallel ridges of low hills rise steadily higher, and converge to Grant's Peak and the well-marked range to its north. The Desatoya range, still farther east, rises abruptly across this low vista, and gives the source of the drain through West Gate. Beyond the Desatoya could be seen the tops of the peaks in the Shoshone range, and beyond these the Toyabe, the highest of all, and running north and south with the others. The mountains looked, in the distance, barren enough, the valleys misty, and the whole doubly interesting to us entering it as almost entirely strange; for it was remarkable how little information could be obtained of it in Carson City.

It was seen that our primary triangulation must depend almost wholly upon points, without our area, and a scheme was projected by Mr. Spiller which was afterward successfully carried out.

From Mount Lyon to Buckland's, to join the party by a direct route, we passed over a plateau of igneous rock to the east of the divide. This is a good range for cattle, and a number were seen about. In the abrupt descent from this plateau to the Carson we found ourselves in a cañon where the intricate mass of bowlders and the steep sides made the passage almost impracticable; finally, coming upon Churchill Cañon, which, toward its mouth, is a broad open drain, we followed to its junction with the Carson, just opposite old Fort Churchill, and thence about two miles along the south bank of the river, and crossed the bridge at Buckland's. Mr. Cowles came in late the same evening, having encountered a rough ascent over lava rock in occupying a station upon the ridge between the Carson and Walker Rivers.

A low peak just north of old Fort Churchill was occupied by Mr. Spiller, and called Churchill Butte. September 11 we left this camp in two parties; the one to proceed by the wagon-road to Wadsworth, to occupy Tu-til Peak, near that place, and to proceed thence to a rendezvous on the Carson at Ragtown; the other followed the road along the north bank of the river and camped at Gates's ranch. Here Mr. Cowles and myself forded the river and occupied a station in the low range south of it. This is a range of barren hills in a desert; they have caused the river to turn away sharply to the north to find a passage for itself. Late at night we recrossed the river to camp, with the pack-train at the Log Cabin. The river was too deep for the packs to cross; they consequently moved along the north bank of the river, and had traveled about ten miles. The next day we followed the river-bank and arrived at Ragtown. This is a rather dreary-looking place, containing only a couple of houses; there is no cultivated ground. It is the first station and the first good water out from Wadsworth, on the freight-road south from that place to Belleville, Ellsworth, and Ione. Ragtown was a station on the overland stage-road, which was running until the Pacific Railroad was finished. It is also the southern terminus of the 40-mile desert of the emigrant-route via the Humboldt River. The desert road extended from Humboldt Lake to

Ragtown. To be compelled to abandon there the exhausted cattle, with their wagons, was no uncommon occurrence with the emigrants. The road is not traveled now.

The water of the Carson is made very muddy by the working of the mills upon its banks in the vicinity of Empire and elsewhere; while the soil of its banks is also exceedingly clayey and alkaline. Below old Fort Churchill fording the river is by no means safe. As far as Gates's (Camp No. 3) much of the land in the immediate vicinity of the river is taken up and fenced in; a little is cultivated, but it is better adapted for hay-ranches. Hay and butter, for sale about the mines, are principally produced.

The river is about 150 feet wide, the bottom generally soft and miry, the banks steep. The water is from 3 to 4 feet deep. There is a good bridge at Buckland's, (the first one below Dayton,) a passable ford at low water at Gates's, and another said to be at Davis's ranch, between Buckland's and Gates's. Except these ranches in the river-bottom, the Carson here flows through a very desert. A little above Ragtown we passed several deserted houses, in ruins, deserted since the overland stage-route was abandoned. At Ragtown the river is quite as muddy as above, and looks very treacherous, with the shifting sandy bottom. Captain Simpson says of the water of Carson Lake, in June, 1859, "The water is of a rather whitish, milky cast."

Soda in quantity is obtained from a couple of small lakes 3 to 4 miles east of Ragtown. The water is simply run into earth vats, allowed to evaporate, and sink into the soil, when the soda remains sufficiently refined for transportation. Mr. Cowles visited these lakes September 15. I returned the same day from Wadsworth, bringing with the pack-train a lot of barley for our future use.

On the 16th we left this place. Mr. Cowles having directions to proceed with the pack-train by way of the Ellsworth freight-road, and await my arrival at West Gate, Mr. Spiller and myself took the old overland road, along which follows the Western Union Telegraph line. We camped at Stillwater, on the slough that connects Carson Lake with the Humboldt and Carson Sink.

Stillwater has a telegraph office and about half a dozen houses. It is the county-seat of Churchill County, Nevada, but at present being remote from travel, is very isolated and dull. There is good land in the vicinity, and artesian wells could undoubtedly be used to advantage. The distribution and flow of the water of Carson River are very remarkable. Three and a half miles below Ragtown the river separates into two nearly equal streams; the left branch, about 2 miles further on, again divides, this making three streams. The central one is called New River. The country here is a great flat about 4,000 feet above sea-level; on the south side is the Carson Lake, shallow, but with generally well-defined shores. It is about 9 miles in length by 6¼ in width. On the north side where the river enters there is swampy ground. This lake is connected with the Carson and Humboldt Sink by the slough before mentioned, which runs nearly north and south, and is about 22 miles in length.

The first branch of the Carson flows into Carson Lake, New River enters the slough, and the third branch turns to the north into the sink. The sink is of much greater extent than the lake. The alternate tongues of water and land, the little islands and pools which form its southern shore, show from a distance the marshy character of the land, and indicate a shallow body of water, and a surface that would be sensibly affected by changes in the water-level. The Humboldt River enters this sink from the north. I was told by persons living along the slough that at times the flow of water in it would be toward Carson Lake and the reverse, depending upon the relative height of the water in the two lakes. At the time of our visit there seemed to be a scarcely perceptible set toward the sink. Captain Simpson, when camped upon this slough, in June, 1859, says: "Carson Lake voids itself rapidly through it to its sink to the north."

The freight-road followed by Mr. Cowles crosses the Humboldt branch of the Carson at Saint Clair's Bridge, and follows on the east of and near the Carson branch.

The slough is also crossed by a bridge at Hill and Grimes, 2¼ miles from Carson Lake.

The travel along this road to Belleville, &c., has made a market for farm-products. There is a number of ranches and one school-house. We also find ranches on the Humboldt branch. The Stillwater road crosses this by a bridge about three miles from Saint Clair's.

The land in this flat, away from the water, is very sandy and almost desert.

Both our parties left this valley on the east, and crossed the Sand Spring Range into Fairview Valley, near the east side of which our routes came together at West Gate. Mr. Cowles crossed the range at the Sand Spring Pass, halting there one day to occupy a mountain station. At Sand Spring water costs 25 cents per head for the animals per night, and wood could scarcely be purchased.

From Stillwater, by the old road, I entered the foot-hills about 18 miles to the north of Sand Spring. We left the road at the summit, and spent several days in the mountains about La Plata and Tarogqua Peak to the north. The range here is called the Silver Hill Range.

Tarogqua Peak rises very abruptly from the plain just east of the southern end of

the sink. The summit is 4,800 feet above the lake, and from it a fine view was obtained. About this peak there are numerous springs, and there is some woodland along the eastern slope of the range, but toward Sand Spring the range is capped with volcanic rock, and entirely destitute of wood and water, (Sand Spring being at the edge of a low flat.)

By the road the summit is about 18 miles from Stillwater, and Mountain Well, within a half mile of the summit, is the only water between Stillwater and West Gate; the water is now scarcely fit for use, the well having been standing open for several years. An old wagon-road leads from the summit to La Plata, about 3 miles to the north. Not many years ago this place, like Como, gave promise of being a flourishing mining-town. There still remain a fine stone and brick foundation and chimney of a large mill which was stopped in the building. A second mill was erected in Black Rock Cañon, near by, about the same time. Now the place has reverted to a pasture-ground for sheep and cattle. There are two small springs of water; one in an old tunnel near the mill, and another half a mile to the north.

Crossing Fairview Valley we found quantities of bunch-grass. The altitude of the valley is but 4,000 feet, and it is a good winter range for cattle; in summer there is no water. The drainage is toward the Humboldt salt-deposit, which is in the northern part of this valley. To the south and in the upper portion of the valley there is a large barren flat. At West Gate there is a single house where travelers can be accommodated. Good water is obtained from a well. The telegraph office, until recently established here, has been discontinued.

We remained at this camp about a week, during which time, trips were made into the adjacent country. One was by the Ellsworth freight-road as far as Tyler's Station, or Chalk Well, so called from the chalky appearance of the water, which does not rise more than a few feet in the well. To return to West Gate we followed a road which connects these places, but makes a detour through East and Middle Gates.

A station was occupied near Chalk Well, on the west side of which is a small spring. At East Gate there is running water and a small vegetable-farm, the nearest market to which is Ellsworth, 28 miles distant. An old road crosses the Desatoya Range here from Putnam Creek. It was made by Captain Simpson, in 1859, in his outward route. (East Gate was called by him the Gate of Gibraltar, and the Desatoya Range the Sedaye or Lookout Mountains.) Following the water-course toward West Gate, water rises to the surface at White Rock. Here, at the junction of Captain Simpson's two roads, a station was built. The fork to the north, which he followed on his return route, crosses the Desatoya Range by Edwards Creek Pass, and this one was afterwards used for travel. From White Rock our route was through Middle Gate, where water again was found at the surface, and thence to West Gate.

Very little wood is to be found in the vicinity, the nearest to the station being about 11 miles distant on the east slope of the Fairview Range. This range is remarkable for the scarcity of water about it; although the peaks rise in even slopes more than 4,000 feet above the Fairview Valley, and some wood and grass abound, yet no running water was found. A dry camp had to be made for the ascent of the highest peak. The formation at its summit is a flaky shale. One large spring is reported on the east slope of the range and to the south of this peak.

A number of cattle range the country and seem to subsist well, though the pasture is undoubtedly scant. It is believed the animals accustom themselves to remain a long time without water. In known cases they come to water at intervals of from thirty-six to forty-eight hours, and as soon as their thirst is satisfied start off to the hills again.

From West Gate the road by Cold Springs, &c., was followed to Patterson Ranch, on Edwards Creek, while a small party made a detour to the north, towards Grant Peak. We ascended along Bench Creek, a small but constant stream running to the foot-hills. Wood was plenty along it. Good pasture-land was found about the summit, there being a plateau of grass-land to the south of the peak. We camped one night near the summit to take observations for azimuth from the peak. Thence we followed a trail that descends very abruptly to Cherry Valley, in the range, 3 miles to the north of the peak. In this valley and its surroundings several hundred head of horses range, in a half-wild state. At Clan Alpine, which is near the mouth of the cañon drain from Cherry Valley into Edwards Creek Valley, there is a small agricultural settlement. A mill erected by a mining company which commenced operations here some years since is now used as a barn. We crossed the valley to Patterson's, directly opposite. A second observation for azimuth in connection with Grant's Peak was made at Patterson's, the tent in camp having been previously sighted from the peak. From Patterson two roads lead to Austin; the one to the north, with the telegraph line, goes by New Pass, Mount Airy, and Jacobsville, and was the road last used by the stage company; the other is by way of Edwards Creek, Smith Creek, and Emigrant Pass, and thence several roads cross Reese River Valley to Austin.

The Desatoya Range being next in order, we proceeded to work up its topography from New Pass south to the drainage of Putnam Creek. In the mountains there is

plenty of water. It is found in nearly all the cañons on the west side, between Gibraltar Creek at East Gate and Edwards Creek. Cedar Creek, next south of Edward's Creek, was meandered in ascending the highest peak from Patterson's. Edward's Creek, and the road along it, and through the pass to Smith's Creek, were meandered by Mr. Cowles. On the east side of the range the two important drains are Smith's Creek and Putnam Creek flowing into Smith's Creek Valley, but both sink soon after leaving the foot-hills. On Smith's Creek a quantity of land is under cultivation. We were encamped upon it for several days, at A. Maestretti's Ranch, who has title to the water-right of the stream. The land has not yet been sectionized by the land-survey. Settlers already located have, however, the first right to purchase when the land is opened for sale. The country drained by these two streams affords a range for cattle that in the summer season, I think, can scarcely be surpassed in the State, and generally the winters are not too severe to pass in Smith's Creek Valley. This valley is at an elevation of 6,000 feet above the sea-level. Two years since there was so much snow that it was necessary to feed hay to the cattle. This with a very large herd is impracticable, and in that winter a number of valuable cattle perished. Fairview Valley, to the west, is 2,000 feet lower, and there cattle can range throughout the winter. Putnam Creek was meandered, and the return trip made by the flat in Smith's Creek Valley. On the western side of this flat is a number of hot springs. There are about twelve of these. The openings are circular, and descend in a conical shape—some of them apparently 6 feet deep. I had not with me a thermometer reading more than 124°, and could not tell the temperature, which was far above the indication of my thermometer. The water was quite clear; the flow very small. Bubbles rose at intervals to the surface. A piece of buckskin held in the water was almost at once acted upon, and when taken out was twisted and stiff and appeared like raw-hide. The circumferences varied from a few inches—mere openings—to one 3 feet across, which was the largest. There is little or no deposit, but some green and black to red fungus. The springs were in one line, extending north and south about 100 yards, on a slight ridge, and on the slopes of which a little grass was growing. There were a number of cold springs, too, intermingled with the hot, but none of them had any flow, the water remaining at one level, and the springs trampled by cattle, so that there appeared no opening in the bottom of them, as in the case of the hot springs.

Two springs, the water of which is quite warm, are found about 6 miles to the north of them in this valley; the cattle drink freely of their water. The barren flat in this valley covers nearly 20,000 acres of land. White sage grows on the slopes to the hills; of this the cattle are very fond. At this season of the year (October) there is no water in the valley. Simpson, in the spring of 1859, speaks of a lake being there, and also of a considerable stream (Engleman Creek) flowing between Smith's and Putnam Creeks. This creek was not to be seen.

From Smith's Creek Mr. Spiller proceeded along the foot-hills to the north, to make a station in the range south of New Pass; afterward to join the northern road and follow it to Mount Airy, and thence to an appointed rendezvous at Birchim's ranch, on Reese River. The rest of the party followed the southern road, which led to the same point.

This camp was 10.7 miles southwest of Austin. We remained there several days duplicating and arranging the notes of the party. Austin was visited, and Mount Prometheus, near there, occupied. We are indebted to Mr. Melville Curtis, engineer of the Manhattan Mining Company, for the bearings and distance to connect this point with an astronomical monument previously established at Austin by this survey. The Reese River Valley presented a good base of operations for completing the survey of the eastern portion of our area, the same purpose that the Carson River and old overland road with its water-stations had served in our route eastward.

The valley of the river here lies between the Toyabe Range on the east and the Shoshone on the west. The Toyabes rise above 11,700 feet and the Shoshone about 10,000 feet. The two ranges converge at the head of the valley and range south into the desert, while the Toyabes to the north of latitude 39° 30′, and the Shoshone north of 39° 15′ decrease in altitude and have little water. The river rises in the Toyabes, about latitude 38° 45′, and flows to the north. A second source is from copious springs, in the valley a few miles south of Birchim's, forming a branch that soon unites with the other. The river-bed crosses the Central Pacific Railroad at Battle Mountain Station, near which place it joins the Humboldt River; water nearly flows to its mouth. The ranges are well wooded, and some of the trees are fit for timber, but the growth is generally stunted. None of the cañon-streams of the Shoshone reach the river. The soil of the valley is much impregnated with alkali; toward the upper part of the valley is a number of grain-ranches; barley is principally raised, the past season being an exceptionally prosperous one. The lower ranches on the river are adapted to making hay.

Mr. Spiller was assigned to work up the topography of the Toyabe Range. He entered the range by way of Big Creek, occupied Geneva Peak, and then worked southward to latitude 39°. Once crossing into Big Smoky Valley by Kingston Cañon, and then recrossing the range to Washington, he finally rejoined the party at McMahon's

Ranch. From this place he made a trip to Poston Peak, at the headwaters of Reese River. In this range, from Prometheus to Poston, a distance of 48 miles, six prominent peaks were occupied. Severe weather was encountered by that party, with snow-storms and cold. Especially on Poston Peak the party suffered severely; there Mr. Spiller had both ears badly frozen. This work occupied twenty days.

In the mean time the party moved up Reese River Valley. The road from Austin to Ione was meandered throughout. From Elkhorn the pack-train went to Washington, in the Toyabe foot-hills, to resupply Mr. Spiller's party. With Mr. Cowles, I made a trip of six days into the Shoshone Mountains. We recrossed the valley to Washington, and then proceeded to McMahon's, to rendezvous with the other party. In the Shoshone Range, from Mount Airy south to Ione Pass, a distance of 40 miles, seven prominent points on the main divide were occupied.

The party was now ready to move westward, through the southern portion of our area, with the object in view to complete the survey of the area in a north and south direction as we moved. At our camp at McMahon's we separated as usual, the next rendezvous being appointed at Ellsworth. Mr. Spiller, Private Niver, and myself formed one party. Our route led us a second time to Ione. This is a mining-town on the western slope of the Shoshone Mountains, a little south of latitude 39° 30′.

The mines have been opened for some years, and promised well when first opened. For several years back little work has been done in them. New capital at this time was awakening the place to a good deal of activity. The same may be said of the town of Ellsworth, across the valley to the west; here, however, new discoveries were also being made. From Ione we crossed the Ione Valley in a southwesterly direction, to Antelope Springs, in the Mammoth Mountains. This valley is but an extension south of the Smith's Creek Valley, the divide between them being very low. The Mammoth Range, here so called, is but an extension of the Desatoya Range. Paradise and Park Peaks, south of Ellsworth, were occupied. The range is not high, but there is an abundance of wood and a number of springs. Ione Valley, east of it, is without water; but it drains well to the south, and gives some pasturage instead of barren flats. To the west the range falls abruptly to barren foot-hills and the Hot Springs Valley with its alkaline flat. The difference of level between Ione Valley and Hot Springs Valley is about 2,000 feet, the same as observed to the north between Smith's Creek Valley and Fairview Valley. The same range forms the dividing line, but on the west the two valleys do not run into each other, as do Smith's Creek and Ione, but a considerable range of hills running east and west separate Hot Springs and Fairview Valleys.

This Mammoth Range is a very distinct line of demarkation between the country to its west and that to the east between latitude 38° 40′ and 39° 30′. The type of country westward extends as far as Mason Valley, and to the Como Range. The Carson River, in its lower part, struggles through it. Apparently finding itself baffled in its westerly course, the desert turns off to the north, to absorb the waters of the Humboldt and Truckee Rivers. The type is a country whose valleys are alkaline flats, and whose mountains are low, igneous hills, without wood and with very little water.

From McMahon's the remainder of the party had returned along the Reese River Valley and crossed the Shoshone Range to Petersen's Ranch, in Smith's Creek Valley, and thence proceeded south through Ione Valley to Ellsworth. Ellsworth is several miles from the summit of the range, and on the eastern slope. The first mines were worked about the site of the town. The impetus now at work is derived from mines on the western or exposed slope of the range. A new town, called Summit City, is being built at the summit, and near these mines. At present water must be hauled there, but it can be brought in pipes from a spring at no great distance.

From Ellsworth, Chalk Well was revisited, to complete the survey of the freight-road from West Gate. Our next camp after Ellsworth was at Welsh's Spring, near the mouth of Marble Falls Cañon, and at the base of the bluffs on the west side of the range. It is but 5¼ miles from Ellsworth. About 3½ miles across the small valley, west of this spring, is the Illinois mine, the principal one of the new mining district of Lodi.

At Ellsworth, I engaged an Indian guide to take a small party through the very dry country lying between West Gate and Hot Springs Valley. Mr. Spiller, the guide, one packer, and myself composed the party. The rest of the party moved southwesterly to Hot Springs Valley, and camped there at some cold-water springs, where they also found some grass for the animals, but were badly off for wood. Our small party was out four days.

The first day, after having occupied the highest point in the hills just west of the Illinois mine, we marched northwest about 9 miles, and camped high up on the rocky slopes of a low peak that was occupied as a station the following day. At this camp the water was in a hole, under and inclosed in the solid rock, and besides being scarce was very difficult to obtain. The guide gave us to understand, however, that in the spring we would find there plenty of water. The wood there was very scant sage-brush. Our second camp was at a spring 7 miles west of this; this spring is hidden in a flat

body of rock; the water was plenty for us, though not abundant. It did not flow, but stood in the sand of one of the rocky ravines. Here we were a few miles east of the Fairview Mountains. Our next camp was at an old arrastra on the west slope of a peak we called Slate Peak. This peak is in the southern extension of the Fairview Range, and there was noticeable another drain cutting through this range to the north of Slate Peak, with sides much more precipitous, however, than those of the West Gate wash that cuts it to the north. Noticing also that Fairview Range is a different formation from those in its vicinity, we can readily conclude that it is much older. At the arrastra referred to was worked the first ore from a mine supposed to be rich in gold: the location is at the head of Fairview Valley. A small mill (5-stamp) was afterward erected in Hot Springs Valley, where water was obtained by sinking a well. Want of capital is assigned as the cause for quitting the work.

The mill is still standing and nearly complete. At the arrastra we managed to obtain a little muddy water by cleaning out the bottom of an excavation previously made for that purpose; there were indications of a spring during part of the year. From this place we crossed the divide at the head of Fairview Valley to Hot Springs Valley, following a road but seldom used since the mine ceased to be worked. The road led to the mill. The whole party then crossed the valley to Dead Horse Well, on the west side of the valley.

There is a copious flow of water from the Hot Springs, in the eastern part of the valley; the water is too hot to bear the hand in it. The deposit is like that of the springs in Smith's Creek Valley.

The alkali flat in this valley contains about 14,000 acres. It is rich in borax, and has been worked to some extent. At Dead Horse Well observations for azimuth were taken, in connection with Basalt Peak near by, which was occupied as a primary triangulation-station. Belleville is south of Dead Horse Well, about 50 miles distant. There are several wells at this place and an abundant supply of tolerably good water. Our route thence was north, along the Belleville and Wadsworth freight-road, to Sulphur Spring, in the Sand Spring flat, 31.7 miles. The road is along the west slope of the Sand Spring Range, and there is no water. At one of the stations (Deep Hollow) water is sold for $1.50 per barrel; it is hauled a distance of 14 miles, from Dead Horse Well. Salt Well is a station three miles short of Sulphur Spring, but the water of the well is not fit for drinking purposes.

The Sand Spring flat covers an area of 20,000 acres; it opens on the northwest to the Carson Slough; the divide is scarcely perceptible. The soil is wet, and water stands in the lowest part.

The water at Sulphur Spring is not very good. Drinking-water is brought from the slough, 10 miles distant. There is a station at the spring. The wood used is brought about 50 miles, by the return freight-teams from Belleville.

In the Sand Spring Range, nine points were occupied, from Tarogqua south to Basalt, 44 miles. We next moved by the southeast of Carson Lake to Allen's Springs. These are the calcareous springs spoken of by Simpson in 1859. At the southwest of Carson Lake there is a large area of porous alkaline ground, that is but little raised above the surface of the lake, and comparatively recent beach-marks indicate the more modern overflows of the water.

Our next rendezvous was appointed in Mason Valley. Mr. Spiller, with the train, proceeded south to Walker River, crossed it at the old Indian agency, and thence moved along the road to Lee's Mill. With Mr. Cowles and one packer I returned to Carson Lake and camped on its southwest shore, near the ruins of an old station. The tules said to be here formerly are entirely gone. We had to carry an old telegraph-pole about half a mile to camp to make our fire; there was no drift-wood. The telegraph line formerly here now passes through Ragtown, &c. The mules would not drink the water of the lake, even after they had been without water for more than 24 hours. The lake was swarming with water-fowl. From here we followed the old road west, past Houton Well, (now deserted,) to Buckland's, where had been our second camp out from Carson; thence we proceeded, by the good wagon-road, to Mason Valley. The Hot Springs in the northern part of this valley have been long known. I here observe that there is an east and west water-shed extending across our whole area from the Toyabe Range, and extending to the Sierras. Starting around the head of Reese River, it joins the Shoshone, then divides Smith Creek and Ione Valleys, and so continues to the west, about the latitude 39° 15′. It finally forms the divide between the Carson and Walker Rivers. It is most marked south of the West Gate Wash, the Farview Valley, and Carson Lake to Buckland's.

To follow from the mouth of Churchill Cañon the broad open drain, one will be surprised to find that it separates from the cañon about 4½ miles from the Carson, and continues with a very slight rise to the divide between the Carson and Walker Rivers, and from this divide to the valley of Walker River. The drain continues the same; indeed the summit cannot be perceived in traveling. Our barometric observations show a constant rise from the mouth of Churchill Cañon south through this drain to Walker River. It would seem to indicate that there had been a connection at one

time between the waters of the two rivers. It certainly presents a very easy pass from one river to the other.

From Lee's Mill we marched in two days to Carson City, following a new road recently established between Dayton and Mason Valley. We arrived at Carson on the evening of the 26th November, when I reported to Lieutenant Tillman. Mr. Spiller made a trip from Carson to Mount Rosa and return before going East.

MINING DISTRICTS.

Four mining districts in operation were visited. Austin, next to Virginia City, is the center of the most prosperous mining district in Nevada. The Manhattan Silver Mining Company, owning several fine mines and a good mill, is now doing the principal work, and is in active operation. A full report of this district has been made by Clarence King.

UNION MINING DISTRICT.

This district has been established about thirteen years. The first discoveries were made by A. J. McGee. It was at first worked actively about eighteen months, and in May, 1876, active operations again commenced. The present recorder is James F. Duckett. The post office is Ione City, Nye County, Nevada; George W. Veatch, postmaster. A buckboard runs weekly from Austin, Nev.; the distance is 51½ miles. The nearest railroad communication is Wadsworth, on the Central Pacific Railroad, 120 miles distant. The district extends 12 miles north and south, and 6 miles east and west, with the foot-hills of the range. The north line is about three-fourths of a mile north of Ione. The mineral belt is from one-half to three-fourths of a mile wide, and, running with the longer line of the district, crops out at intervals through the 12 miles. Croppings show both in cañons and upon spurs on the west slope of the range, and about one-third of the distance from the summit to the foot-hills. The range trends north and south; the lodes have the same direction, and dip to the northeast, uniformly with the country-rock. The walls are covered in places with a thin seam of white clay, and these give the richest deposits. Vegetable impressions have been found, but no fossils. Chloride is the principal ore found; it has been worked by crushing dry and roasting. The water-level has not been reached in the mine. The ore contains a good deal of iron, and some lead and antimony. Gold is found in all the ore, generally in paying quantities. The principal mines now worked are the Storm King and the Clipper. The first is being worked by the Ural Silver Mining Company; an incline has been run 350 feet, with two levels several hundred feet in length; the amount of good ore in sight is not great. In connection with this mine a shaft is being sunk, several hundred yards from the ledge, to strike the incline at a depth of about 800 feet, if the incline continues with its present pitch. This company is also putting up, a few miles south of Ione, a fine mill with capacity for 20 stamps. A revolving furnace (White) will be used, and improved machinery throughout. At the present writing, it should be completed. In the Clipper mine several inclines have been run, a small force was at work, and gold has been taken from it; the work was not on the vein at the time. Some fifteen other mines are considered in favorable condition for working; on all of them a considerable amount of labor has been expended.

The Pioneer Mill, owned by James M. Cammack, is in the town of Ione; it has been idle for some time. It has a fine engine, and the reverberatory furnaces used for roasting the crushed ore are in good condition. The stamps are out of order. When first opened the mines were found to contain pockets of rich chloride, and paid well.

Two veins run with the mineral belt, and the excavations made show them to be extended. The value of the ore extracted is claimed to have far exceeded the amount expended on the mines. The ore will generally be easily extracted by inclines and levels run on the veins. Wood is abundant, and there is a running stream at Ione. The cost of freight from the railroad is 2½ cents per pound.

MAMMOTH MINING DISTRICT.

The first discoverers were R. B. Craig and James Donelly. It was organized December 23, 1863, and has been worked with more or less vigor since that time. Patrick Downey is recorder. The post office is Ellsworth, Nye County, Nevada.; P. O. Tyler, postmaster. The route of the buckboard from Austin, through Ione, terminates here. The freight-route is from Wadsworth, on the Central Pacific Railroad, about 110 miles distant; freight from Wadsworth is 2½ cents per pound; returning, the price is 1½ cents per pound.

Willow Spring, a short half mile west of the town, is the center of the district; from this point to the center of the bounding lines north, south, east, and west, is 5 miles. The area of the mineral croppings is about one-half mile wide by 3½ long, the longer line crossing the Mammoth Range east and west, and the mines are located on both side

of it. The range trends north and south; the lodes on the east trend north and south, and those on the west, northeast and southwest. The eastern slopes are gentle, and there the discoveries are in the foot-slopes, and adjacent to the town. The country-rock is granite. None of the mines there are being worked. The Mount Vernon mine was most extensively developed, and is considered valuable. It is now flooded with water, which, in the granite, is reached at 100 feet.

On the western slope the strata are much exposed, the descent being very abrupt. The discoveries range through about 1,000 feet in altitude, commencing near the summit, and extending a little more than half way down the slope. The deposits are richest in the slate and limestone. A metamorphic rock also abounds. The Last Chance, Grant and Colfax, and Canada mines, on all of which work was being done, are in the same belt of rock. It is about 600 feet wide, and cuts across the country-rock. The Lisbon mine, also on this slope, has been worked to a considerable extent. The Last Chance may be taken as a sample of the first three; it has three shafts or inclines, respectively 100 feet, 133 feet, and 40 feet, with about 70 feet of levels, run on the vein. The hanging wall is a seam of indurated clay, about 4 feet thick, the foot-wall slaty limestone; barren horses of slaty limestone occur at intervals, but the continuity of the vein seems well established. The ore is principally chloride, with a little iron, and traces of copper. Assays show its value to range from $68 to $236 per ton, with an established average of over $80 to the ton. The dip is southwest; the inclination to 60 feet is 75°; below that, as far as developed, it is 85°. The Grant and Colfax has a shaft of 60 feet, with a level of 40 feet on the ledge, and a tunnel has been run 100 feet, that will reach the ledge 110 feet farther on. The Canada has a tunnel run 35 feet on the ledge. These three mines have been actively worked since their discovery, which is recent. The ore will be easily extracted; its transportation to the mill, which must be on the eastern slope, to be convenient to water, will be a matter of some difficulty. It is contemplated to build a wagon-road; it can be graded to the summit in about 1 mile. This would give a grade of about 450 feet from the summit to Ellsworth; where the mill is to be situated, the distance would be about 4 miles, with an easy grade. Mr. W. H. Raymond, of Oakland, Cal., is negotiating for the Last Chance mine, and it is expected to shortly erect a new mill at Ellsworth. The one already there is a 10-stamp mill, with Stedefelt furnace, 750-pound stamps, an engine of 40-horse power, and with 2 settlers and 5 pans. Wood is abundant and convenient, and there are unfailing springs just above the town. Gold is found in the ore, and said to average from $10 to $15 to the ton. The indications of increased prosperity for this district are good.

LODI MINING DISTRICT

Was discovered by F. M. Pearson, A. Welsh, and J. H. Williams, and was organized in September, 1875. It has been actively worked since that time. The recorder is Joel Holden. Ellsworth is the post office. From Wadsworth the distance is about 100 miles; the road to within 10 miles of Lodi being identical with that to Ellsworth and Ione. The district is bounded on the east by Mammoth district, south by the old Wellington road, west by the Hot Spring Range, and north by the Wadsworth road. The principal ledge is situated on the east slope, and at the eastern extremity of a somewhat detached group of hills, but which have here a ridge extending several miles east and west. Lodi Peak, the highest point, is 6,486 feet above sea-level, and 1¼ miles west of the ledge. This ledge trends a little west of north, and the mineral croppings show an area about 1 mile long by 300 feet broad. The walls are nearly perpendicular, being an exceedingly hard black rock, apparently a fissure, retaining well its width. The richest deposit is found where the ore vein contracts to a couple of feet, the remainder of the fissure being here filled with a loose, friable, yellow-colored rock. The ore is carbonate. It contains about 7 per cent. of antimony, a good deal of iron, and about 25 per cent. of lead-carbonate. The assays give about $15 to the ton in gold. The Illinois mine on this ledge has one shaft 60 feet, and another 90 feet, deep, on the vein. In the latter shaft is a drift 20 feet north, at a depth of 60 feet. Several locations have been made on the extension of this mine. The Lodi mine, northwest of this ledge, has a shaft 115 feet deep, with a cut across the ledge at 60 feet; its walls are perpendicular, and trend east and west. From the Illinois mine about $20,000 worth of ore has been shipped to San Francisco; a quantity of this assaying $500 to the ton. The average of the assorted ore is $300 to the ton. This mine has also been purchased by Mr. Raymond. No mill has been erected as yet. The shafts and drifts will be run in the vein matter. There is no water near the mines. Two springs, Welsh and Wilkinson, are on the opposite side of the valley which separates the Lodi hills from the Mammoth Range; they are, respectively, about 3 and 3½ miles from the Illinois mine, in a direct line. The highest one is 90 feet above the level of the mine. The lowest (Welsh) is about the level of the mine. Timber could be obtained from the Mammoth Range. On this, the west side, however, the timber only grows near the summit. Freight from Wadsworth costs 2½ cents, and returning 1½ cents.

There is a large number of cattle in the vicinity of these three mining districts. For Ione and Ellsworth, the source of grain and hay supply is Reese River Valley, and this is also the nearest point to Ellsworth. Reese River Valley is distant about 8 miles from Ione, 17 from Ellsworth, and 34 from Lodi; the distance to Lodi is largely increased by a necessary detour through Burnt Cabin Summit to cross the Mammoth Range. From this valley, the cost of forage at Lodi, at present prices, would not exceed 3½ cents per pound for barley and 2 cents for hay; at Ellsworth, 3¼ cents for barley and 1¼ cents for hay; at Ione, 3 cents for barley and 1¼ cents for hay.

It is contemplated to build a narrow-gauge railroad from Battle Mountain, on the Central Pacific Railroad, to Austin, Nev. This would make the distance from railroad communication for Ione 51½ miles, and for Ellsworth, via Petersen's Ranch and the Lower Reese River Valley, 55 miles. From Lodi to Austin, by the route through the valley, would be about 62 miles, as against 100 miles to Wadsworth. The advantage in supplies of water, forage, and the character of the road-bed would also be in favor of the Austin route.

Lauder City was built on Big Creek, about the mouth of its cañon from the Toyabe Range; a great deal of prospecting was done, but to little purpose, and the place was deserted for Austin when that camp became prosperous. A few ranches are now found along the creek.

Following up Big Creek, and crossing the range into Kingston Cañon, we find another old mining camp, on which a great deal of money has been expended. The Sterling Mill, at the mouth of this cañon, is held in good order; it is a 20-stamp mill, the motive being furnished by a turbine water-wheel. The remains of two other mills, from which the machinery has been removed, are found not far from it.

At Washington also a camp was started, and there is quite a little village of houses, all but two of which are now deserted.

There is no doubt that much labor, toil, and money have been expended in this country on worthless mines. The failures, however, are often due to other causes; prominent among which are undue expectations, lack of facilities for transportation; and again in one case a thriftless expenditure of a company's money, and in another a lack of means. These camps were started at a time when mining was a rage in Nevada; now it has sobered down very much. The success of Austin, and the undoubted fact that a large quantity of mineral does exist in these mountains, must lead us to hope that, with proper care and management, a future day will see this a prosperous mining region.

WORK DONE BY THE PARTY.

The party was in the field 83 days, and including Mr. Spiller's trip to Mount Rosa, after our return to Carson, the following will indicate the work done, viz:

Number of main camps	29
Number of side camps	47
Number of miles meandered	1,073.89
Number of miles traveled and not meandered	633.42
Number of mountain stations occupied with a 10-inch or 20-inch instrument	22
Number of topographical stations occupied, being either included in the triangulation or three point stations, with 30-inch instrument	79
Number of additional three-point stations	244
Number of aneroid-barometer stations	501
Number of cistern-barometer stations	104
Number of variations determined by observations on Polaris	27
Number of azimuths determined	3
Number of latitudes determined by sextant	30

A great number of points were fixed by cross-bearings, care being taken in this respect with regard to every topographical feature of importance distinguishable from two or more stations. For this purpose two methods were introduced by Mr. Spiller and used. In the first, all the sights to points, taken at an occupied station, were numbered consecutively around the horizon from one upward; then, on sighting any one of these points from a second station, a convenient note was made, citing the number or designation of the previous station and the number of the sight from it to the point to be fixed by the cross-sight. In the second, on a sketch made from a previous station, was recorded in brackets, at the sketch of the point cross-sighted, the sight taken from a second station. Both these methods obviate the necessity of making more than one complete sketch of a view having nearly the same aspect from two different stations. They tend to cause stations to be occupied in pairs with reference to a number of prominent topographical features, and this I believe to be an excellent practice.

The altitude of points fixed by cross-sights was determined by angles of elevation or depression from barometric stations.

TRIANGULATION.

The main points on which our triangulation depends are: Mount Rose, 10,820 feet: Mount Lyon, 8,815 feet; Tutib Peak, 7,062 feet; Basalt Peak, 6,599 feet; Fairview Peak, 8,412 feet; Tarogqua Peak, 8,771 feet; Grant Peak, 9,965 feet; Desatoya Peak, 9,921 feet; Paradise Peak, 8,662 feet; and Bunker Hill, 11,405 feet, and Poston or Davies Peak, 11,756 feet, in the Toyabe Range. From each of these stations repeated angles were taken to Cory's Peak, the highest point in the Wassuck Range, and situated just west of Walker Lake; and from Mount Rose, Basalt, Paradise, and Davies Peaks angles were taken to White Mountain Peak, which is to the east of Benton, Cal. The triangle—Davies, Mount Rose, and White Mountain Peaks—which will be completed when the angle at White Mountain Peak is measured, is a very large one. The lengths of its sides are—

	Miles.
From Davies to Rose	142.45
From Rose to White Mountain	134.25
From White Mountain to Davies	88.00

The instruments were returned in good condition, except that the wet bulb of psychrometer No. 8 was broken, being blown from the top of a peak by the wind.

Mr. Spiller was untiring in his efforts to do the work thoroughly and well.

Mr. Cowles, in addition to his designated duties as meteorological observer, constantly performed those of a topographer as well, and in both instances with credit to himself.

RATIONS.

The twenty-five days' rations taken at Carson lasted the party as far as West Gate The day after we reached that place, the team in charge of Corporal O'Neil arrived from Carson, with provisions for the party for the remainder of the season. Taking out sufficient to last us as far as Dead Horse Well, I instructed the corporal to return to Ragtown for grain left there by me, and, returning through West Gate, to proceed to Ellsworth, leaving there some grain; thence to proceed by the old Wellington road to Dead Horse Well, and leave there a supply of rations for fifteen days and the remainder of the grain. These orders he faithfully carried out, and proceeded to Reno, where he reported to Lieutenant Tillman. On our arrival at Dead Horse Well, the rations there were taken up, and lasted through the field-season.

FORAGE.

Although much of this country is well adapted to grazing loose animals, there is little luxuriant growth of grass. At the time of the year in which we traveled through it the pasturage was very dry and short, where there was any at all. In every instance we were compelled to pitch our camp either on ground already taken up by ranchmen, or, more often, in places where the pasturage was much too scanty to subsist the animals by feeding loose overnight. We were thus compelled to carry or purchase grain at all times, and hay was fed whenever it could be obtained. The animals came in in excellent condition, having been fed during the season a daily average of 6¼ pounds of barley and 6.3 pounds of hay. The price of barley varied from 4¼ cents per pound at West Gate to 3 cents in Reese River Valley and 2½ cents in Mason Valley. Hay was 2½ cents per pound at West Gate and 1 cent in the valleys.

A list of road-distances, with remarks as to wood, water, &c., is transmitted herewith.

After the disbandment of the parties at Carson, and in accordance with instructions, I proceeded to Camp Independence, California, with the animals, &c., used by the parties in the field. I left Carson December 4; two non-commissioned officers and three privates of Company D, Twelfth Infantry, and four civilian employés, being of the party. We had in charge two six-mule teams and one light wagon, with eighty-five animals in all. We arrived at Camp Independence, without accident, December 13. I at once turned over the property to Lieutenant Wotherspoon, Twelfth Infantry. This completed my duties in the field.

Respectfully submitted,

R. BIRNIE, JR.,
First Lieutenant Thirteenth Infantry.

Lieut. GEORGE M. WHEELER,
Corps of Engineers, in charge.

Appendix E.

EXECUTIVE AND DESCRIPTIVE REPORT OF LIEUTENANT CHARLES C. MORRISON, SIXTH CAVALRY, ON THE OPERATIONS OF PARTY NO. 2, COLORADO SECTION, FIELD-SEASON OF 1876.

OFFICE OF UNITED STATES GEOGRAPHICAL SURVEYS,
WEST OF THE 100TH MERIDIAN,
Washington, D. C., April 1, 1877.

SIR: I have the honor to render the following executive report of operations of party No. 2, Colorado Division of the survey, during the field-season of 1876, together with a brief description of the country traversed and its resources:

EXECUTIVE REPORT.

The Colorado Section, consisting of Party No. 1, which was taken charge of by Lieutenant Bergland, Corps of Engineers, shortly after its leaving the rendezvous-camp, and my own party, No. 2, was organized at Fort Lyon, Colorado, late in August.

The parties took the field on the 29th and 30th of August, respectively. The personnel of the one under my charge was Lieut. C. C. Morrison, Sixth Cavalry, executive officer and field astronomer; Mr. Frank O. Maxson, topographical assistant; Mr. George M. Dunn, meteorological observer; Mr. Lanier Dunn, aneroid and odometer recorder; A. R. Mitchell and Martin Sanchez, packers; Edmund Rocroft, laborer; Thomas Kennedy, packer and cook.

From Fort Lyon the party proceeded to Trinidad, following generally the drainage of the Purgatoire, following on the west side, thus cutting all drains coming in on that bank. About eight miles above Trinidad we left Purgatoire, following up Long's Cañon, crossing the divide at its head, and coming down upon the upper waters of the Canadian. Here a belt of country was closely surveyed, locating the heads of that river. Thence we proceeded across the heads of the Vermejo and Point, via Elizabethtown and Taos Pass, into the valley of the Rio Grande. Entering the Taos Valley, some two miles southeast of Fernandez de Taos, we passed through the lower edge of the valley, striking the Rio Grande at Cieneguilla; thence following the main stream, through the cañon of the Rio Grande known as the Caja del Rio, the party proceeded to Santa Fé, at which point rations were obtained and comparisons were made of meteorological instruments with those of the Signal Department, as the survey of the belt of country to the south was to be referred for its vertical element to this point. Three days' observations were taken here for horary curve, and the triangulation-station on the hill just north of this city was re-occupied for development of the base and system of triangles to the south. The party left Santa Fé September 21, and on the 23d Old Placer Peak was occupied by Mr. Maxson, as triangulation-station, while the mining district of New Placers was examined by myself. Stations were then made on the Sandia and Manzano Mountains for triangulation and topography.

At Mosca Peak the party was detained four or five days by cold heavy rains—the equinoctial storm. From the Manzano Range we worked eastward over the plateau extending from the base of these mountains and re-occupied Pedernal Peak; thence, proceeding southwest, through the plains of the many alkaline lakes, we passed the Salt Lake proper, from which salt chemically very nearly pure is obtained in coarse crystals. We recrossed the Manzano Range by Comanche Pass, having first occupied Osha Peak for triangulation and topography, and worked up the eastern slope of the range. Descending Comanche Cañon, we crossed the plateau extending to the Rio Grande, striking the river opposite Los Lunas. From Los Lunas a meander line was run to Socorro, on each bank of the river; the one by Mr. Maxson, the other by myself. At this place rations were obtained, and the party proceeded to the Socorro Mountains, camping at Culebra Springs. Socorro Peak, Culebra, and Polvadera Peaks were all occupied for triangulation and topography. Thence we proceeded to the Magdalena Mountains, leaving the main camp in cañon Del Agua. Mr. Maxson and myself, with one packer, ascended the peak, expecting it would be necessary to stay away one night and a day for triangulation, topography, and azimuth observations. Before reaching the top we were caught in a blinding snow-storm. We made camp at the edge of timber-line, and then had to wait four days, without tents and with insufficient blankets, with no water except that obtained by melting snow, and but scant supplies. Our animals suffered much from want of water and grass, as we had nothing we could melt snow enough in for them, nor would they eat, as they suffered from thirst. The point was very important in the system of triangles. Over three hundred angular readings were made on this one point by Mr. Maxson, and an astronomical azimuth was determined by myself. He afterward occupied Garcia Peak, in the same range, while I examined the mineral deposits in these mountains.

From the Magdalena Mountains we proceeded via the Quinza drain to the Ladrones

Mountains, then, after occupying these for triangulation and topography, to Sabinal; here the party was divided, Mr. Maxson, Mr. George Dunn, and one packer proceeding up the Puerco Creek, while the main party proceeded to Los Lunas, where the side party was to rejoin them. Again we were reminded of the approaching winter season. The mountains inclosing the valley were covered with snow. From Los Lunas we moved to Ojo de la Casa, on the western slope of the Manzanos, thence southward to Abo Pass, running along the base with traverse-lines up the drains and occupying South Manzanos Peak, working up thus the western draining and topographical forms of these mountains. In the low range to the south several subordinate points were occupied for topography as three-point stations, from which accurate sketches, instrumentally checked, were made. The belt extending to the river was thus traversed. From Socorros we proceeded to Fort Craig, at which point we were to obtain rations. Arriving there November 10, we were detained by a snow-storm for three days. From Fort Craig we worked up the belt east of the river between the Chupadero plateau and the Rio Grande up to Abo; thence we proceeded to Mesteñito Spring; here we were overtaken by another snow-storm, covering the grass entirely. To save our animals we proceeded to a ranch, at Antelope Spring, where forage could be obtained, marching all day in a blinding snow-storm, unable to see a hundred yards ahead of us. The trail had to be followed by occasionally noticing little depressions in the snow. We arrived late in the afternoon. That night the thermometer fell to 16½° below zero. Fortunately none of the animals were frozen, although at other ranches we afterward heard of fourteen being frozen to death in one herd and twenty-nine in another, and doubtless if we had not been able to obtain the shelter of a stockade ours also would have been lost. This extreme cold determined us to start on the return trip. Moving to Los Posos del Puis, we there reached the point farthest southeast covered by our work during the season. Moving northward over the main route from Fort Stanton to Anton Chico, we passed through there November 30. The weather having moderated somewhat, we occupied Mesa Chupaines for triangulations; thence, crossing the Gallinas Creek at the La Liendre, we went up Cañon del Agua, and from there to Fort Union by way of Las Vegas. At this point we received the most cordial treatment at the hands of the officers. From Union our route led to the Vado de la Piedra, or Rock Ranch ford of the Canadian; thence, by the Dry Cimarron route to the Chaquaqua Cañon. Leaving the old Dodge cut-off a short distance beyond this, we went by the new route, which crosses the Purgatoire at Nine-Mile Bottom and makes junction with the Trinidad road a short distance south of Alkaline Station. This route we followed to Fort Lyon, at which post the party arrived December 14. The topographical instruments used during the season were first Buff and Berger 8-inch transit, graduated to 10 seconds horizontal limb, capable of being read by a practiced eye to 5 seconds. This instrument was very good, and worked to entire satisfaction during the season; it was used on all mean-triangulation stations. One of Stackpole's 7-inch transits, one Young, and one Cassella meandering transit were also used. Horizontal distances were measured by odometer, checked by numerous three-point stations, the whole depending upon the primary and secondary triangulation-points of the system developed from the base near Santa Fé, the co-ordinates of the extremities of which were astronomically determined in 1873.

The meteorological instruments used were two cistern barometers, three aneroids with the complement of hygrometers, maximum and minimum, and pocket thermometers. One of the cistern barometers used had Lieutenant Marshall's improvement, consisting of a closely-fitting inner tube filled with plaster of Paris, completely enveloping the barometer tube, excepting opposite the scale, where a slit was made to permit reading. This barometer was used for mountain work, and was very much stronger, supported as it was, than the ordinary tube. It was dropped from the shoulder of the meteorologist once, falling on end; it then fell over to its side on a board floor and did not break. Later in the season it was broken by a kick from a mule; even then it was not shattered, but cracked throughout the length of the tube opposite the scale where unsupported. Although a little heavier, it is certainly much better able to stand a season's work than the present form, which does well enough for the standard for camp. The field astronomical instruments used were one sextant and artificial horizon.

The season's work was very satisfactory; each of the assistants, Mr. Maxson, George M. Dunn, and Lanier Dunn, bending every effort to secure such results as deserved the highest commendation. Working in the most untiring manner, Mr. Maxson's labors were rewarded by his triangles closing very finely. The meteorological work also attested the care of Mr. Dunn. Each member of the party endeavored to contribute to a harmonious whole, and succeeded. Between seven and eight thousand square miles of country were completed, in accomplishing which the party traveled between eighteen and nineteen hundred miles, occupied fifteen triangulation stations, one hundred and ninety-one three-point stations, and about fifteen hundred minor stations, the altitudes of all which were determined and entered into the vertical representation of the country. The transportation returned in fair condition, considering that nearly all the time they had no corn and much of the time but scanty grass, and at many camps were without water.

GENERAL DESCRIPTION OF THE COUNTRY.

The country traveled by the party was entirely south of the Arkansas, and may be divided into three belts: First, that extending from that stream to the south to the Raton spur of the Rocky range; second, the heads of the Canadian and its branches in the main range; third, the valley of the Rio Grande and the plateau between it and the Pecos. This first belt constitutes a vast rolling plateau of uninteresting aspect, treeless, save along the brooks which seek outlet in the Arkansas. Little agricultural land is found; that little is confined to the immediate vicinity of the streams. Valuable this land certainly is as grazing land, but it has little to attract the stranger. In the belt, nearly a hundred miles across, but few ranches are found. Along the immediate valley of the Purgatoire, evidence of the farmer is seen, and it is claimed, doubtless justly, that the finest of fruits thrive in this valley. The grain there produced is very promising. Once out of the immediate valley a wide expanse of gently rolling monotonous country pains the eye in the hot, dry air of an August noonday. Here and there it is broken by an arroyo, in which an uncertain supply of alkaline water may be found. These arroyos deepen as they approach the Purgatoire, and may well near their mouths be termed cañons, boxed up as they are by their sandstone walls, rendering the country almost impassable, which, farther out on the plains, can be traversed in almost any direction by wagons.

Here little is seen of more interest than the large herds of antelopes, which, with gentle swinging gait, keep just out of rifle range.

On the main freight wagon route from West Las Animas, but a year ago the terminus of the Atchison, Topeka and Santa Fé Railroad, we find a few ranches. After leaving Sizer's ranch on the Purgatoire, at which point the road diverges therefrom, we first come to the old stage-station known as Alkali Station. Here is a little hut, with stables and corral, used as a shelter to the stock-tender and his animals. It is now deserted, or was at the time we passed. The water is slightly impregnated with alkaline salts. Farther on are Vogel's ranch, Bent's Cañon, Lockwood's ranch, and Hogback; of these, that at Bent's Cañon is much the most promising ranch. Near Hogback is a sharp, bare hill of plutonic rock, from which this station gets its name. About 8 miles from Trinidad the road again approaches the Purgatoire at a point where the valley widens out, rendering available considerable arable land, depending simply upon proper irrigation and cultivation to provide ample supplies for the town springing up at El Moro, the present terminus of the Denver and Rio Grande narrow-gauge road, which, with enterprise, is feeling its way to the south, gathering the freight of New Mexico. This latter town has all the bustle of the last railroad town, and may eventually be extended to unite with Trinidad, the older and larger place, some 5 miles beyond, the growth of which seems to have increased with the proximity of El Moro, rather than to have been sapped by it, as is so frequently the case. Situated as these are at the entrance to Raton and Long's Cañon Passes, they are less likely to die out as the road passes on beyond. The coal-field in the vicinity of Trinidad will contribute to its support. Beyond the cul-de-sac in which Trinidad is situated, the character of the country changes entirely. The rise from West Las Animas to Trinidad, of 2,158 feet, is very gradual. Here the foot-hills of the main Rocky range and the Raton spur close in. Leaving the main stage-road at Trinidad, our course lay up the Purgatoire for about 8 miles. Ranches, with their cultivated fields, claimed each inch of ground capable of tillage, till leaving the stream we follow a less frequented road, ascending the cañon with even grade. Gently rising, we pass beyond the piñon growth marking the lower hills and reach the pine-covered country extending to the heavily broken plateau of the Raton Pass, hardly to be styled as a mountain range in comparison with the bare, bold crests of the serrated range from which it springs. Although not reaching the elevation, it offers in its broken surfaces, its many cañons, its sharp rises and sudden cuts, almost as great difficulties to engineering skill in locating a road across it as the more prominent ranges. From the Purgatoire to Elizabethtown is a fan-like succession of secondary ridges, broken by the cañons of the Vermejo, the two branches of the Poñil and the Van Brimmer Park. This whole section is well grassed, timbered, and watered, and for a mountain range could not be excelled for cattle. For a railroad pass to Cimarron and country east of the mountains it is, while higher, of so much better grade than the Raton Pass, that Long's Cañon would probably be adopted in preference to the latter, having for its southern outlet the course of the Canadian to Red River Station. For a direct pass to Elizabethtown it could be only made available by the most careful study of the minor topography, deviating in many places from the present located wagon routes. Elizabethtown is situated at the head of a fine park at the base of the Bald, between this peak and the main range; with perhaps less bustle than in former days, it is still a mining town of some little prosperity. From Elizabethtown to the entrance of Taos Pass extends a beautiful park, presenting no difficulty to a railroad route; the pass is a good one, and will doubtless be eventually utilized; the wagon road is fair, but in need of work.

Taos Valley is one of the finest grain-growing districts in New Mexico, extending from

the base of the mountain nearly to the Cañon of the Rio Grande, from the mouth of the United States Mountain Cañon to the Cañon of Pueblo Creek. On it are Fernandez de Taos, the old Mexican town, near which is the Pueblo de Taos, the old Indian town, former capital of the Pueblo Nation, Rancho de Taos, formerly subordinate to the Fernandez Plaza, but now nearly equal in population, and Los Cordovas, at the junction of the streams watering the other towns. The Rio Grande opposite this valley is boxed in a great cañon about 800 feet deep, extending 60 miles to the north, on both sides capped with basalt. The Arroyo de Cieneguilla runs just east and south of the basalt, and from the little town on the other river-bank of the same name the stream divides the two formations; on the west is the purplish black of the basalt, on the east the variegated, tinted, illy formed granite from the nearly fused quartz and feldspar, with its white, pink, and red shades, to the dark gray of the more micaceous, friable rock. On the west the direct result of the internal heat is vomited forth upon the earth. On the east is found the metamorphosed sandstone, burnt crisp by the more indirect action. Farther down, the river again cuts asunder the basalt plateau, but to open out at La Joya into a wide valley, needing but American enterprise to reclaim it from a sandy plain and render it rich in crops of cereals. Even the simple efforts of the Mexican have been rewarded with rich vineyards and fair orchards. The native fruit, excepting the grape, is not of fine flavor, but where the trees brought from the East have been cultivated the result has been very encouraging indeed. La Joya, Los Luceros, Plaza del Alcalde, San Juan, and San Ildefonso are found on the river, and Santa Cruz, Pojoague, Cuyamungue, and Tezuque on the tributary streams, where crossed by the main road leading to Santa Fé. Between Santa Fé and the Rio Grande is a low range of hills. South of Santa Fé the main range dies out. The mountains beyond these, east of the Rio Grande, in prolongation of the main axial line, are more broken up: they lose their continuous ridge-like form. North of the Galisteo are the Cerillos, which are but low hills, azoic in formation, broken by many basaltic dikes. They would be of little importance but for the mines of argentiferous galena and copper. Several thin mines of turquoise have been rudely worked by Indians, Spaniards, and Mexicans. There are throughout the whole region evidences of old mines, worked probably by the Spaniards with Indian labor, before the latter drove their former conquerors from the country. South of the Galisteo are the old Placers, the Puerto or New Placer Mountains, the Sandia, San Pedro, and San Isidro Mountains, in all of which are mineral deposits. The formation in these ranges is mainly azoic; toward the west there are carboniferous croppings. The Sandias are capped with fossiliferous limestone. The Placers have auriferous copper-ores, also iron and coal. The Puerto or New Placers are full of metalliferous ores and deposits, copper, lead, iron, gold, and silver ores. The Sandias have many traces of copper and lead. The ores of the whole region require careful handling, with more skill than has yet been given them. There is no doubt as to their existence in paying forms if properly treated. About both the new and old Placers gold-diggings that would give very large returns with hydraulic washing extend nearly around the entire bases. The water-supply is very limited, but with the advent of capital means will be found to bring water there, to reclaim its cost twenty-fold. Real de Dolores, Real de San Francisco, Alamocito, San Antonito, San Antonio, and Tijeras all are found in the basins between these mountains. West of the Sandias is the Rio Grande Valley. South of the Sandias are the Manzanos, the northern portion of which range consists of a low plateau broken up by numerous cañons, the branches of the Tijeras Cañon, Coyote Cañon, Cañon del Norte, Cañon Infierno, Cañon de los Ejes and Moyas. The western slope is abrupt, indeed cliff-like; the dip of the rock to the east renders it gently rolling country in that direction. Just south of Cañon Moyas the range shoots up into the Mosca Peaks, which run above timber-line. The limestone is again here found. From Mosca southward to Manzano Peak the elevation of the higher points is about 10,000 feet. The formation is similar to that of the Sandias. The cañons on the west are short and bounded by high, cliff-like walls; those on the east and southeast are longer and more tortuous. The range can be crossed by Hell Cañon, also just north of Mosca, following up Tejique Creek, or by Comanche Cañon, south of Mosca. That by Hell Cañon is a rough wagon-road, the others but horseback-trails. The main drainage is to the east; Chilili Tejique; Torreon Manzano, Osha, and Abo Creeks being the principal waters. On the west there are no running streams, but along the base are found Ojo de la Casa, Ojo del Trigo, El Hediondillo, Cañon de Salas, Ojo del Cañon de Monte Largo, Cristoo, and Justamente Springs. Farther out on the plains are Ojo de la Cabra, the Ojuelos, and Ojo de los Casos. At the Ojuelos is a fine sheep-ranch. From the base of the mountain the country slopes gently to the river in nearly uniform grade. The river valley proper, or that which can be placed under irrigation with but little trouble, is in places from 3 to 5 miles wide. The soil, while sandy, is rich in salts nourishing to plants, and, with water, produces the most inviting fields. Hardly a tenth of the present arable land is now utilized. Many little towns extend along the river from Albuquerque to Fort Craig; on the west bank are Atrisco, Padillas, Pajarito, Isleta, Los Lunas, Los Charez, Ranchitos de Belen, Belen, Pueblitos de Belen, Los Jarales, Punto del Bosque, Bosque, Ranchitos de Sabinal, Sabinal, Pueblito de Sabinal, Picacho de Sabinal, San

Carlos, San Geronimo, Alamillo, Polvadera, Limitar, Escondido, Socorro, San José, San Antonio, San Antonito, and San Marcial. On the east bank are Ranchitos de Isleta, Los Pinos, Perolta, Valencia, Tome, Ranchitos de Tome, Constancia, Casa Colorada, Valleta, Chihuahua, Las Nutrias, Ranchas, San Francisco La Joya, La Joyita, Sabina, Pueblito de la Parida, La Parida, Bosquecito, Valverde, La Mesa, and Contradera. These towns vary in population from a few families to perhaps 1,800. The principal towns are Isleta, Los Lunas, Belen, and Socorro on the west bank, Valencia, Constancia, and La Joya on the east bank. Socorro is marked by much more American enterprise than the majority of New Mexican towns, arising largely from the mines in the Magdalena Mountains bringing money into the section. The approach of a railroad will brighten up the prospects of the country, which needs but enterprise supported by capital to make it rich in its own resources. The grapes will be probably the main source of income of those living in the valley proper. West from Socorro are the Socorro Mountains, a short ridge of azoic rock. Copper is found here. West of this range are the Magdalena Range, running north and south, which have throughout their whole extent mineral ledges and deposits. A few fissure-veins with quartzite wall-rocks are found, but generally the one is in indefinite deposits. The northern end of the range has, for surface rock, carboniferous limestone resting on azoic quartzite. It is here that argentiferous galena, carbonate, and yellow oxide of lead are found. At present the mines are not extensively worked. The ores exist in sufficient abundance to well pay for working with experienced management, but with haphazard work, of men ignorant of proper treatment of the ores, they are apt to obtain a reputation which will keep capital away. Just west of these mountains is a low range of hills, near the Corona del Pueblo Spring, in which are found argentiferous copper-ores. Sinking prospect shafts and mining with little or no system has been done here with the poor results almost sure to follow such treatment of the deposits. North of these are the Ladrones, a sharp uplift broken into a serrated edge difficult of approach, and so nearly destitute of water as to discourage the prospector; traces of copper are found throughout the range. The southwest spurs are capped with limestone. The eastern rocky slope is quartzite. Mule Spring, in a drain of this southern spur, is one of the few water-croppings in the range proper. The northern slope is very precipitous. The range has little to support life; grazing is not as good as usually found in mountains; hence less game and very few cattle are seen. The point as a triangulation-station is very important, connecting the surveys from the north and west with the system south and east. The peculiarity of this range, as of nearly all mountains in Southern New Mexico, is the suddenness of their uplift. With but few foot-hills of much importance, they rise directly from the plains extending about their bases; hence, the water-sheds being small, few streams are found. The plains, with their porous soil and nearly level surface, quickly drink up the rains and give them out only by the rock-croppings at the springs which run but a short distance. From Abo Pass, extending to the south, is a much broken plateau of sandstone country, west from which is a narrow plateau of drift; very little water is found in this belt. The few springs are the Ojo Sepulto, Ojo Parida, Ojo del Cibolo, and Ojo de las Cañas; and the tanks are Aguejes de los Torres, de los Tomasceños, and del Cañoncito on the west, and the Llano and Coyote Springs on the east. The water supply at the Parida is very good; that at Llano Spring has been developed by digging; that at the other points is very limited. On the eastern portion of this belt is a sharp basaltic butte, standing in the center of a limited volcanic overflow of the sandstones.

Abo Pass, which separates this belt from the main range, is a low divide, well calculated for a railroad-pass; indeed, the best in connection with the cañon Piedra Pintada to be found any place along the range this far north. At Abo and Quara are old ruins, presumably Spanish, built at the first occupation of the country, before Europeans were expelled by the Pueblo Indians. The two main buildings, in each case from their form Catholic churches, are about 100 feet long, built of stone—a laminated sandstone. The walls vary from 3 to 7 feet thick, the former being the usual thickness; the latter that of the abutments. Their European architecture is probable from being built in that form of a cross usually adopted by the descendants of the Spaniards in their churches. Arches are also found, in which respect they differ entirely from the ruins found in the San Juan country, which are ascribed to the Aztecs. In both ruins the altars were at the north end of the building.

East from the mountains extends the immense plain, broken by the mesa-edge on the south known as the Jumanes. Farther east are three hills known as Las Animas, one of which we called Rattlesnake Hill, from the number of those snakes we saw there, probably from three to five hundred. In sixty-five minutes three of us killed seventy-nine snakes, varying in size, all of the same species. The largest had thirteen rattles. They had been out to the south of the hill, and toward sunset came in for their night-shelter in the rocks. Southeast of these hills about 18 miles are more alkaline lakes. Wells have been dug near them, giving fair water. The station is known as Posos del Pino. From here northward to Pedernal the country is greatly rolling, with fair grazing. Beyond Pedernal it is more or less broken by drains leading into Cañon Piedra

Pintada and Cañon Blanco. From Cañon Blanco the route was through the plateau country, extending north to the Dry Cimarron, all of which, to Fort Lyon, was described in your annual report of 1876.

I desire to take this opportunity to tender my thanks to the members of the party for their cordial co-operation in the work, as also to the officers of the military posts visited for their uniform courtesy.

I am, sir, very respectfully,

CHAS. C. MORRISON,
First Lieutenant Sixth Cavalry.

Lieut. GEO. M. WHEELER,
Corps of Engineers, in charge.

APPENDIX F.

EXECUTIVE AND DESCRIPTIVE REPORT OF LIEUTENANT M. M. MACOMB, FOURTH ARTILLERY, ON THE OPERATIONS OF PARTY NO. 2, CALIFORNIA SECTION, FIELD SEASON OF 1876.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL SURVEYS WEST OF THE 100TH MERIDIAN,
Washington, D. C., April 30, 1877.

SIR: I have the honor to submit the following executive report of the operations of party No. 2, California division, of the survey under your charge during the field season of 1876.

The party rendezvoused at Carson City, Nev., during the latter part of August and the first part of September, being one of the parties organized there under your supervision. It was composed as follows: Lieut. M. M. Macomb, Fourth Artillery, executive officer and field astronomer; Frank Carpenter, topographer; Alfred Dubois and Sergeant G. W. Ford, Twelfth Infantry, recorders; H. W. Henshaw, naturalist; A. R. Conkling, geologist; W. H. Rideing, general assistant; two packers, one teamster, and two cooks.

During the first few days of September, Mr. Carpenter was employed in working up the topography of Eagle Valley, in which Carson City is situated. On the 7th, he was sent out with a small party for the purpose of making, if found advantageous, a primary triangulation-station on Spanish Peak, north of the Central Pacific Railroad, at the same time surveying a line through country that would not be traversed by the other parties, the trip to occupy seven or eight days. Meantime arrangements were made for the storage of all surplus property, the purchase of forage for use during the season, and the supplying of parties in the field. For this latter purpose it was found necessary to increase the means of transportation, and, accordingly, on the 13th, six team-mules were purchased by telegraphic authority from the Quartermaster-General.

While at the rendezvous, Messrs. Henshaw and Conkling found ample employment for their time in their respective branches, the former in making collections in zoology, the latter in visiting the various mines and mineral and thermal springs in the vicinity. Besides these duties, both rendered assistance to the other members of the party in keeping up the hourly series of meteorological observations commenced August 26, a detail being constantly employed day and night.

The work especially assigned to my party was the survey of Lake Tahoe and the neighboring country, the line of the Central Pacific Railroad being the northern limit. Part of this area lies in Nevada, part in California, and when mapped will appear upon Atlas-sheets 47 D and 56 B. A short description of its general topographical features will be given here.

Beginning with the peaks just north of the well-known Carson Pass in the Sierra Nevada, there is a well-marked bifurcation, the main ridge here sending out a bold and lofty spur to the northward, itself continuing on, but with diminished height, to the northwest. This spur is loftier than the main ridge, having an average altitude of 9,800 feet. It culminates to the south in Freel's Peak, and to the north in Mount Rose, in whose vast mass it terminates. Both of these points are over 10,800 feet above sea-level. It is called the Eastern Summit, in contradistinction to the main ridge, which is known as the Western. Southwestwardly from Mount Rose runs a long spur, reaching almost to the western summit, between which and itself it leaves a narrow valley. There is thus formed in the bosom of the Sierras a triangular basin with a length of about 37 miles and a base of perhaps half that dimension. At the southern apex of this triangle the Upper Truckee takes rise, and meanders its way for about 15 miles through the beautiful and fertile Lake Valley, finally expanding into Lake Tahoe, which occupies the northern part of the basin. Vastly increased in volume, it issues from the lake, through the narrow valley above referred to, a heavy and rapid stream. Flowing west a short distance, it changes its course to the north, and then making a grand

sweep to the east, flows onward, finally emptying into Pyramid Lake, which has no visible outlet. Thus the waters of the Lake Tahoe Valley are tributary to that great interior basin, that peculiar system of so-called "sinks," in which all the waters of Nevada, with a few trifling exceptions, are swallowed up. The eastern summit breaks down quite precipitously to the east into the valley of the Carson, some of the branches of which river rise in the little valleys of Hope, Faith, and Charity just east of Carson Pass. The western summit slopes gradually to the west, all its waters from Carson Pass to Summit Station on the Central Pacific Railroad (some 43 miles) being collected into the American River by its south, middle, and north forks and their various branches, by which, as might be expected, numerous valleys and deep cañons are formed.

It was not until the 14th of September that the party moved into the area assigned to it, when camp was made at Glenbrook, on the east shore of Lake Tahoe. The route followed from Carson was over the King's Cañon road, which, winding up the slope of the eastern summit until it attains an altitude of some 2,500 feet above our camp in Eagle Valley, descends to the lake, giving grades practicable for heavy teams. Another route between Carson and Glenbrook, known as the Clear Creek route, and used by the Lake Tahoe stage-line, joins the first mentioned at the summit. A steep grade on this road not far from the summit causes the King's Cañon route to be preferred for heavy teaming. The stage-route is about a mile and three-quarters shorter than the other, by which the distance is about fifteen and a quarter miles. Travelers by either route pay toll at the summit.

Glenbrook is very prettily situated on a small bay about the middle of the east shore of the lake. A brook flowing through a deep and shady glen empties into this bay and gives the place its name. Settled in 1860, it was the first place of any permanence on the lake, and is now the principal village, claiming some four hundred inhabitants. It is the center of the Lake Tahoe lumber-trade and possesses four saw-mills and a planing-mill. The saw-logs are floated here from lumber-camps on the north, west, and south shores of the lake, and I was informed that about 25,000,000 feet of sawed lumber are annually turned out. The principal markets are Virginia and Gold Hill, the great mining center of Nevada. The lumber is now carried to the top of the eastern summit by means of a narrow-gauge railroad built in 1875. As the grade of the wagon-road from Glenbrook to the summit is about 290 feet to the mile, the railroad avoids this by running some three miles north of Glenbrook, then ascends the slope by a zigzag, the general plan of which would be a flattened and distorted Z. The angles of the Z are arranged as the ordinary railroad Y, and thus a considerable difference of level is overcome by moderate grades. From the summit a flume between 9 and 10 miles in length runs down the Clear Creek Cañon, and by this fire-wood or lumber can be delivered within a mile of Carson. Received here by the cars of the Virginia and Truckee Railroad, it can be carried to the points where it is wanted.

One of the first objects to strike the eye after reaching Glenbrook is a prominent mass of basalt just to the south, which bears the interesting name of Shakespeare's Cliff. A moment's careful inspection will show on an almost vertical escarpment not far from the summit a mass of greenish-gray lichens standing out plainly against the dark surface of the rock. A glance at this will without any stretch of the imagination transform it into a truly striking resemblance to the head and bust of the great poet as seen in profile; the high forehead, massive brows, and pointed beard being wonderfully reproduced. This was plainly visible from our camp in the neighborhood of a mile to the north. Situated about the middle of the eastern shore, and not half a mile from it, with an altitude of some 800 feet above the lake, the cliff affords a fine panorama of the entire western and the greater part of the northern and southern shores. Of the lake itself I attempt no description, as that will be found in full in the report of the geologist, but the following facts in connection with it may be of interest:

The geographical position of the lake is well fixed by the one hundred and twentieth meridian of west longitude transversing its length, and the thirty-ninth parallel of north latitude crossing its southern end. Its developed shore-line may be set down in round numbers at 70 miles, and its superficial area at about 188 square miles, of which two-thirds lies in California, the remainder in Nevada. Five counties border upon it: Washoe, Ormsby, and Douglas in Nevada; Eldorado and Placer in California. The principal settlements are Glenbrook, on the east shore, Rowland's, on the south, and Tahoe City on the west. The others are McKinney's, on the west, near Sugar-pine Point, Yank's on the south, and Hot Springs on the north shore, and State-line Point. At all these points accommodations may be found for tourists. During the summer and fall Tahoe City is connected with Truckee on the Central Pacific Railroad by a daily line of stages carrying passengers and mails, while Glenbrook is similarly connected with Carson. A small steamer makes a daily tour of the lake, touching at all the places mentioned. A stage is also sometimes run between Hot Springs and Truckee. A good road connects Glenbrook and Rowland's, whence a moderately good one runs to Yank's. Thence to McKinney's there is a trail, very bad, near Emerald Bay, and from McKinney's to Tahoe City there is a road. A rough trail, passable for riding or pack

animals, connects Tahoe City, Hot Springs, and Glenbrook. Finding at Glenbrook an excellent camping-ground and good feed for the animals, it was decided to make a main camp here and study the features of the eastern summit by detours to the south and north. Accordingly, on the arrival of the topographer at this camp, a trip was made to the south, and a main station established on a well-defined point, showing well from the stations in the neighborhood of the base, near Virginia City. About this time, also, a second small party, in charge of the geologist, was ordered to make a trip around the lake, putting up signals on points along its borders, which might be of assistance in establishing the shore-line, and at the same time obtaining reliable information concerning the trails and roads about the lake.

The work along the range to the south having been completed as far as thought necessary from this camp, a detour was made to the north. During this trip the narrow-gauge railroad already referred to was surveyed and the lake shore meandered far enough to the north to be connected with without difficulty on the home trip.

A main triangulation station was also made and the topography of the range finished as far as possible to the northward. Marlette Lake was likewise visited and surveyed. This little lake is beautifully situated in a basin just west of the main ridge, and considerable interest attaches to it from the fact that it is the source from which the Virginia Water Company intend drawing their supply. It is easily reached by a very fair wagon-road which leaves the stage-road at Spooner's Station, about five-eighths of a mile from the summit. It drains into Lake Tahoe, but by damming its outlet it has been increased to many times its original size. It now measures about $1\frac{1}{4}$ miles in length by half a mile in breadth, with a superficial area approximating to 300 acres. Our barometric observations make its altitude 7,750 feet or 1,548 feet above Lake Tahoe, and high enough above Virginia City and Gold Hill (some 16 miles distant in a straight line) to give a good head there. In order to get the water across the ridge a tunnel is being pierced through the granite rock composing it about 3 miles north of the lake where the ridge is narrowest. This tunnel is in a fair way toward completion, and will have a length of nearly 4,500 feet, with a cross-section of about 6 by 8 feet. The water will be led to its west end by a ditch or flume. On the eastern slope the flume has been built and is in operation, being at present fed by some of the mountain streams of that slope. Pursuing a tortuous course down the mountain-side until a steep slope is reached, the flume discharges its contents into a pipe which descends rapidly until it reaches its lowest point at Lake View, on the low ridge separating Eagle and Washoe Valleys. Following up this ridge for some 5 miles the pipe delivers its waters to a flume which conveys them to their destination, Gold Hill and Virginia.

Returning from this trip to the Glenbrook camp, September 24, we were delayed a day on account of its being necessary to discharge the two packers and a cook, whose places I was fortunately able to fill without much difficulty. Meantime the party sent around the lake having reported, camp was moved on the 26th to a point near Rowland's, on the south shore of the lake.

About 3.3 miles south of Glenbrook the road passes Cave Rock, which is the most prominent object on the eastern shore, being easily discernible from our stations on the western ridge. It is a mass of porphyritic trachyte rising some 150 feet above the lake, the road being carried round its base on trestle-work. The rock derives it name from a cave extending some 30 feet into its side. The top and sides of this cavern are darkened by a peculiar pitchy deposit similar to that described in full in vol. v, (Zoology, p. 559,) of the published reports of this survey.* Between 2 and 3 miles farther Zephyr Cove is reached, once a popular stage-station, but now deserted.

In the palmy days of staging, before the completion of the overland railroad, the road was kept in beautiful condition, and sprinkled twice a day. Although not traveled nearly so much as formerly, it is still an excellent road, and a great deal of farm and dairy produce passes over it to the Virginia markets. In about 4 miles from Zephyr Cove Small's Station is passed, at which point the Kingsbury Grade road crosses the eastern summit, coming out in the Carson Valley about 3 miles south of Genoa. A little less than a mile farther on Kearney's Station is reached. When the the State-line was run it was found to pass directly through the inn, and it is said that guests may dine either in Nevada or California by simply changing sides at the table. The boundary monument on the lake shore near by was visited and brought into the scheme of triangulation. Here we left the main road, which continues up the east side of the valley, and took the road along the south shore of the lake to Rowland's, and camped in a meadow near by. Leaving the main party here, the topographer and myself, with a small party, started for Freel's Peak. Bad weather and a broken barometer obliged us to devote two days to our observations here. A small monument and a bottle containing records found on the summit showed that the peak had been visited Sep-

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* It is worthy of remark that careful observations by the naturalist of the party do not confirm the theory there advanced ascribing the deposit to lizards, but point rather to the opinion expressed by Prof. Cope, that it is produced by some small mammal, probably the *Neotoma cinerea*.

tember 15, 1874, by a reconnoitering triangulation party of the United States Coast-Survey. On the completion of our work here the topographer made a detour into Hope Valley, working down the valley of the Carson almost to Genoa, and returning by the Kingsbury Grade, thus finishing the topography of the eastern summit included between that road and Hope Valley. Meantime, finding it impossible to use the Army wagon on the west side of the lake, I sent it back to Carson, with all surplus impediments for storage, and had sufficient stores to last the remainder of the season deposited at Glenbrook, where was left also the wagon and such team-mules not used as riding or pack animals. The means of transportation was thus reduced to ten pack and twelve riding mules and one extra animal.

Breaking camp at Rowland's we proceeded south through Lake Valley, striking the main road in about 4½ miles. Following this some 3½ miles, Osgood's toll-house is reached. Here the road leaves the Truckee River and winds up the slopes of the western summit, which it crosses, descending the western slope through the cañon of the South Fork of the American, which is here a rapid mountain stream. The road crosses it by a bridge at Slippery Ford, and soon after passes a lofty and almost perpendicular cliff bearing the hackneyed name of "Lover's Leap." At Strawberry Station, a mile farther on, there is another toll-house. Following the main road some 4 miles farther, we left it at the Georgetown junction and passed up into the mountains, camping at Sawyer's Ranche, within easy striking distance of our objective point—Pyramid Peak, in the western summit. Clouds and mists hanging about the peak interrupted our work greatly, and kept us two days at this point. There is a fine stock range here, affording pasturage for several hundred head of cattle. I was informed by the proprietor that in the season he produced as much as 125 pounds of butter a day, though at present he was not making more than 60. The stock is generally driven out about October 15 to winter in the Sacramento Valley. The distance from Sawyer's by road to Strawberry is 12 miles; by trail only about 3½. The trail is passable for riding animals, but dense groves of small trees make it impracticable for heavily-laden pack-mules. Locating the next main camp at Yank's, on the southern shore of Lake Tahoe, and on the west side of Lake Valley, surveys were made of Fallen Leaf and Cascade Lakes, and Tallac Peak occupied for topographical and triangulation purposes. This peak is a most interesting one, not only on account of its own beauty as seen from the lake, but because of the beautiful view from its summit. Situated only about 3 miles from the lake in a straight line, and fully 3,500 feet above it, the bird's-eye view obtained is simply perfect. The Hot Springs Hotel, at the northern end of the lake, was clearly visible, as well as the houses of the settlements on the south shore. The little steamer, a white speck upon the blue expanse, was seen making its daily rounds.

Fallen Leaf and Cascade Lakes, and many others of less size embowered in trees, lay beneath our feet. To the southwest Pyramid Peak rears its rugged crest, embracing between itself and Tallac a deep rocky depression, dotted with numerous pools, and known as the "Devil's Basin."

Fallen Leaf Lake (118 feet above Tahoe) is easily accessible from Yank's by a wagon-road which leaves the head of the lake at Gillmore's Ranch, and passes on several miles farther to a fine soda spring; from there on a trail leads nearly to the summit of Tallac. A herd of several hundred Angora goats find subsistence on the slopes of the mountains south of Gillmore's Ranch.

Cascade Lake (330 feet above Tahoe) is oval in shape, and about a mile long, deriving its name from a fine water-fall some 250 feet high at its head. For interesting facts relating to the glacial origin of these lakes I refer to the report of Mr. Conkling.

On the 17th of October we left Lake Valley and proceeded on our way around the lake. In the neighborhood of Emerald Bay the trail is exceedingly steep and difficult, and some trouble was experienced from several of the pack-animals rolling down the steep slopes. After leaving here, however, no difficulty was met with. The bay is about two miles long by three-fourths of a mile broad, narrowing down at the entrance to a quarter of a mile. At its extremity is the summer residence of Mr. Ben. Holladay, jr., which is entirely concealed in a grove of aspen and willow. A more charming retirement it would be hard to find.

From the north point of the bay to Rubicon Point the shore is steep and rocky, but the trail from there to McKinney's is excellent. Before reaching McKinney's the trail crosses a bold projection known as Sugar Pine Point, from the fine trees of that name growing there. A large lumber-camp located here afforded a good opportunity of witnessing the mode of lumbering generally in vogue on the lake. The trees are sawed instead of cut down and converted into saw-logs as they lie. These logs vary from 20 to 60 inches in diameter, the length varying to suit purchasers, generally between 20 and 30 feet. Perhaps the most interesting feature is the great wagons on which the logs are hauled to the lake. These are made immensely strong, the wheels being constructed of a section cut from a saw-log, and are from 3 to 3½ feet in diameter, being about 6 inches broad at the tire, and bulging out at the center. The heavy cross-beams on the wagon-body are furnished with iron stirrups of peculiar construction, in which rest

the ends of heavy planks used in loading. The wagons are drawn by six or eight yoke of oxen. To give an idea of what can be done by these wagons it is a matter of record that 14,900 odd feet of lumber in the shape of saw-logs has been placed upon one of them. This was popularly known as the "boss load," and photographs of it can be obtained at Truckee.

We took advantage of the lumber-camp smithy to have our mules shod, many of them being badly in need of it, and while waiting occupied several topographical stations in the western summit.

A good trail, opened some years ago by Mr. McKinney, runs from here to Georgetown, crossing a branch of the Middle Fork of the American some eight miles from McKinney's, and called by him the Rubicon. From here we moved up the valley of Blackwood Creek, containing abundance of fine feed, and camped near Twin Peaks. The weather being excellent, a day sufficed for our work here. To the north we saw several fine points, (among them the Needle and Granite Chief,) which we intended to occupy, though our hopes of this were somewhat dashed by Mr. McKinney's statement that he looked for snow every day, and that the probabilities were that in a short time the higher peaks would be impassable.

Meandering the lake-shore as far as Tahoe City, we moved thence down the Truckee and encamped October 26 at the head of Squaw Valley, which drains into that stream. This valley is well watered, and produces abundance of fine hay. A cattle-ranch is located here, and we found the ranchmen busily engaged in collecting their stock previous to driving them out for the winter. They informed us that a trail led out of the valley to the west, passing near the peaks we wished to occupy, while a second trail constructed by them during the summer permitted egress to the north. Wishing to ascertain the proximity of the peaks, I ascended a higher point at the summit of the pass, called Fort Sumter from its peculiar outline, but a heavy mist completely shut out the view.

The 27th was stormy and rainy, and during the night about 4 inches of snow fell, which continued all the next day. The stock was driven out just in the nick of time, as the meadows were now covered with about 8 inches of snow. Several bales of hay left by the ranchmen afforded feed for the mules, so that I was not obliged to move out at once, which I was unwilling to do, as this would be our last chance to work up the topography of this portion of the range.

The 30th, breaking bright and clear, afforded an opportunity of making a final attempt at the "Needle," or, should this prove impracticable, at least of making a topographical station on the high point near the summit of the pass. We found the snow deeper than we expected, but finally made the point only to find, however, that the mists, which had been gathering during the ascent, completely enveloped the higher peaks, and in a few moments our own, giving us just time to catch a fleeting glimpse of the Needle, about a mile and a half to the northwest, "pointing its lean finger to the sky" as if in mockery at our efforts.

On this trip I obtained for the first time occular evidence that there are deer in these mountains by a well-marked trail in the snow. From this it was evident that the animal, driven from the mountains by the snow, had taken a hasty survey of the valley, then turned in its tracks and made a rapid exit. I decided to follow its example, and on November 1, after having meandered Bear Creek, which we had passed a few days before, left the valley in a snow-storm. Soon after reaching the Truckee and Tahoe turnpike the snow ceased, allowing the road and river to be meandered as far as Truckee on the Central Pacific Railroad. Learning that Lieutenant Tillman was encamped only about 4 miles from here, on Prosser Creek, I moved on there to consult him concerning the connection of our triangulation. Finding that he and his topographer were absent on a trip to Castle Peak, we proceeded to work up the topography north of Lake Tahoe, camping in Martis Valley. From here we attempted the ascent of Mount Rose, but found it impracticable from the west. Camp was then moved to Hot Springs, near the extremity of the promontory known as State Line Point. This is one of the most interesting places on the lake, and the view is exceedingly beautiful, especially at this season, when the mountain peaks, capped with snow, contrast strongly with the dark pine forests clothing their rugged sides. For the accommodation of tourists, a hotel and a number of small cottages have been erected, the water of the springs being utilized for bathing purposes. The proprietor received us with true Californian hospitality, tendering us free use of the cottages and baths, which kindness we were glad to take advantage of. While here the survey of the lake was completed, and connection made with the monuments of the California and Nevada State line. Lieutenant Tillman visited us at this camp, and obtained information with reference to points occupied by us to the southward. Learning of our failure to reach Mount Rose from the west, he determined to attempt the ascent from the north. Of the success of this attempt we had the unexpected pleasure of being eye-witnesses. While occupying a high point north of the lake and some 7 or 8 miles southwest of Rose we were delighted to observe, through the telescope of our instrument, Lieutenant Tillman at work. The next day we passed over the eastern summit, connecting with the work previously

done, and camped at Franktown, in Washoe Valley. November 9, we reached the rendezvous-camp at Carson, where Messrs. Henshaw and Conkling were detached from the party under orders received from you early in the season. We then passed up the Carson Valley as far as Genoa Hot Springs, connecting with work previously done. Upon the completion of this we proceeded to occupy a peak in the range of mountains east of Carson Valley, and known to us as Mount Como. This is a high point almost due south of the peak, in the same range occupied by Lieutenant Birnie's party early in the season under the name of Mount Lyons.

On the way to our peak a meander was obtained of Eldorado Cañon, the general course of which is nearly north and south, its mouth being near Dayton on the Carson River. Soft gray limestone occurs near the entrance quite plentifully, and is burned in a lime-kiln at this point. A good toll-road runs up this cañon, and a small stream meanders its way through it, crossing the road at frequent intervals. The slopes on either side are bare of vegetation, except now and then a little sage or a scrubby pine. The lack of vegetation allows one to see easily the fantastic shapes into which the elements have carved the rocky sides, but the heat in summer must be very great. Near the head of this cañon is situated the Virginia City Company's coal-mine, the product being a lignite of fair quality. Proceeding onward some 3 miles from the mine we camped near the base of what is locally named Mineral Hill, where lie the springs in which Eldorado Creek rises. This hill stands up well when viewed from the neighborhood of Virginia City, and was observed, I believe, by the party there under the name of Como. The point known to us under this name, however, lies some four miles o the southeast, and is considerably higher, being in the main range, which runs nearly tnorth and south, and is called in the neighborhood the "Como Range," after an abandoned mining-town of that name near Mount Lyons. It has also been frequently called the Pine Nut Range, after the timber of that name, which was once quite plentiful, but which has now been almost entirely cut off for fuel.

About 28 miles in length, it breaks down on the north into the valley of the Carson River, which sweeps round that end, and on the south into that of the West Walker. About 4 miles north of us the ridge sends out a spur to the eastward, which drains to the north into the Carson, and on the south into the West Walker. Just to the east lies a barren, sandy valley containing a small alkaline flat. To the east of this is a range of low, sandy hills, beyond which lies Mason's Valley, through which flows the main stream of the Walker River. The eastern slope is quite steep, while the western falls gradually off to the Carson Valley, being broken up into valleys and cañons by minor ranges and foot-hills. Mineral Hill is high enough to hide the Carson Valley to the northeast, but it is visible for nearly its whole length south of Genoa.

Finishing our work here we returned to Carson by way of the Brunswick Cañon, through which runs a fair wagon-road, which crosses the cañon by a bridge at the Brunswick Mill, where there is a toll-house.

Leaving Carson again, the quartz-mills along the river between Empire and Dayton were located; then passing through Virginia City the survey of the Geiger Grade, leading thence into Steamboat Valley, was taken up where the work of Lieutenant Symons's party ceased, and camp was made at Steamboat Springs, on the Virginia and Truckee Railroad. These springs are among the most interesting in the State, and have been known for many years. Clouds of vapor continually rising make them conspicuous for several miles. From the name one might be led to expect that the emission of this vapor would be accompanied by a sound like that made by the exhaust-steam of a western river steamer, but I noticed nothing of the sort. The rocky mound in which the springs lie is situated at the base of a spur of Mount Rose. Numerous small pools are found on the summit of this mound, the temperature of the water varying from blood-heat to almost boiling. Besides the pools, long irregular fissures occur from a few inches to a foot in width, and extending to a considerable depth. In these the water can be seen boiling and bubbling violently, sometimes disappearing entirely, then rising to view again. In some of the pools I noticed a white deposit like that frequently seen in sulphur springs. The water when cool is perfectly drinkable, and is not so impregnated with minerals as to prevent the use of soap in washing. A hotel has been erected here and has connected with it a commodious bath-house, which is built directly over some of the fissures above referred to. The springs are easy of access, being by rail only 11 miles from Reno on the Central Pacific Railroad, and about 20 from Caason. They are considerably resorted to during the summer on account of the medicinal properties of their waters. Steamboat Creek flows a few hundred feet east of the springs and empties into the Truckee. Steamboat Valley contains a considerable amount of arable and grazing land, and widens out on the north into the Truckee meadows.

Our next camp was at Glendale, a small hamlet on the Truckee, and formerly a station on the old transcontinental emigrant-road. Passing from here up the east side of Steamboat Valley along the base of the range running north from Mount Davidson several topographical stations were made on the ridge, and a small portion of the shore

of Washoe Lake meandered. The rendezvous-camp was reached November 25th, and the party disbanded.

We were in the field eighty days, during which time we traveled in all 1,024 miles, of which 654 were meandered. Seven main triangulation stations were occupied, and fourteen secondary. Eight hundred and thirty-four stations were made on meander line, and one hundred and two three-point stations as checks or for the location of important points. One hundred and three cistern-barometer altitudes were observed besides the aneroid determination at each meander station. The highest point reached was Freel's Peak, in the eastern summit of the Sierras, 10,862 feet above sea-level, the lowest 4,222 feet, on the Central Pacific Railroad.

But few sextant latitude observations were needed as checks, since every important point could be located by triangulation. The instrumental outfit of the party was the same as that generally allowed and needs no special mention. For interesting points concerning the natural history and geology of the area visited, I beg to refer to the special reports of Messrs. Henshaw and Conkling.

Very respectfully, your obedient servant,

M. M. MACOMB,
Second Lieutenant Fourth Artillery, U. S. Army.

Lieut. GEO. M. WHEELER,
Corps of Engineers, in charge.

APPENDIX G.

PRELIMINARY REPORT ON EXAMINATION AT THE COMSTOCK LODE, BY JOHN A. CHURCH.

VIRGINIA CITY, NEV., *June* 30, 1877.

SIR: I have the honor to submit a short report of the work in the Washoe mining district during the month of June, 1877, in accordance with your instructions. Arriving on the ground on the 11th day of that month, it was obviously impossible to do more in the short remainder of the fiscal year than to place and enter upon the prosecution of the work.

I find that the period of seven or eight years which have passed since the last extended study of this region has been the period of greatest activity and greatest change the Comstock lode has ever witnessed. The mines have been opened a thousand feet deeper than in 1869, and have changed from a vertical to an inclined system of working, in correspondence with the change in the dip of the vein. To meet this altered condition of things the mines have all established a separate system of hoisting for the incline; these are being raised to the head of the incline by a "giraffe" and then dumped to a car which is run upon the cage and hoisted as formerly through the vertical shaft. None of them attempt to raise the ore by one continuous hoist through both the inclined and vertical shafts. Preparations are now completed in one shaft and going on in two others for resuming the extraction through vertical shafts by sinking in the east country-rock of distances in two cases of more than half a mile from the outcrop of the vein.

Changes quite as important have been effected in machinery. The geared pumping-engines, which were formerly used by all the mines, have been replaced in most of them by very elaborate and expensive direct-acting compound engines, controlled by the Davey valve gear, which has been somewhat modified in this region. The pumps are all of the Cornish pattern and are now raising water from depths of 2,000 and 2,300 feet. Direct-acting hoisting-engines have also been introduced at one shaft, and the speed of hoisting increased in those mines which are extracting great quantities of ore. Self-dumping skeets have taken or will take the place of the ordinary cage and car in two of the deep shafts. These alterations in the method of working are all important in view of the great depths to which these mines will probably be carried. The machinery now on the ground is sufficient for depths of 3,000 feet, and the method of working the incline and vertical shafts separately adapts it to much deeper sinking.

Underground engines are used in considerable numbers for pumping, hoisting, and ventilation, and as these are all worked by compressed air, the mines along this lode offer probably the most extensive series of air-compressing engines to be found in any district. They are mainly of two types, the Burleigh and a modified Waring.

All these changes have produced great effects upon the mining of the district and the financial fortunes of the owners. As now instituted, the mining industry of Washoe presents important opportunities for studying the effect and economy of modern mining-machinery.

Ventilation and pumping have become questions of especial importance. The heat

of the vein, and also of the country-rock, has on the whole increased, or, at all events, high temperatures have become more common as the workings gained in depth. Observations on this point have been collected, and a system will soon be instituted which, it is hoped, will afford valuable information upon the best means of overcoming the heat of the mines.

The deep adit called the Sutro Tunnel has penetrated about 17,500 feet, and is now about 2,750 feet from the lode. It is advancing at a rate of speed which should take it to the vein about March, 1878. It will, however, reach the line of the deep shafts sunk in the east country rock some time next month. Its completion cannot fail to have important results upon the drainage of a vein that is liable to sudden outbursts of water in great quantities, as the Comstock is.

The milling of the ores has undergone some alterations, but nothing so extensive as those above indicated in the mining. The latest-built mills are models of convenient arrangement and economy. On the whole, the ore which is now extracted is richer than any which has been obtained since the earliest period of mining on the Comstock vein, and the problem of milling these ores with as high, or a higher, return as was formerly obtained from less-rich ores has been successfully grappled with.

I have thus sketched, in a very general way, the condition of the field to which I am assigned. My work so far has consisted in preparing for the observations necessary to a study of the ventilation and drainage of the vein and the position of the ore-bodies found below the 1,000-foot levels.

I have great pleasure in acknowledging the courtesy and frankness with which every one connected with the mines has received me. No restraint has been placed upon investigation, but, on the contrary, the survey can count upon the active co-operation of the mining companies, even at some trouble and cost to themselves.

I am, very respectfully, yours,

JOHN A. CHURCH,
Mining Engineer.

LIEUT. GEO. M. WHEELER,
Corps of Engineers, in charge.

APPENDIX H.

GEOLOGICAL REPORT ON THE PORTIONS OF WESTERN NEVADA AND EASTERN CALIFORNIA BETWEEN THE PARALLELS OF 39° 30′ AND 38° 30′, EXPLORED IN THE FIELD-SEASON OF 1876, BY MR. A. R. CONKLING.

NEW YORK CITY, *April* 16, 1877.

SIR: The area examined is bounded on the north by a line drawn through Truckee, Cal., and Washoe City, Nev.; on the east by the Mount Davidson Range and the Como Mountains; on the south by Job's Peak and Pyramid Peak; and on the west by the Western Summit and the Truckee River.

Nearly all of this region is covered by granite, with occasional outbursts of basaltic rocks. No fossils are found except at the State prison quarries, one mile east of Carson City. There is abundant evidence of the former existence of glaciers in the mountains bordering Lake Tahoe. Thermal and mineral springs occur in several localities. A few ore-deposits are found within the area explored in 1876, but only one of them possesses sufficient importance to deserve more than a passing notice.

Two ridges, running north and south, traverse this section of country. They are termed the eastern and western summits. Lake Tahoe separates the one from the other. The latter range is more broken up by precipitous cañons and minor ridges than the former. Both the summits are sparingly wooded, from the base to the crest-line, and may be regarded as parallel lines of elevation.

Having given an account of the general features of the area explored in 1876, I now propose to take up the geology in the following order:

1. Description of the Carson Valley and vicinity.
2. Sketch of Lake Tahoe.
3. The eastern summit.
4. The western summit.

THE CARSON VALLEY.

There are several thermal springs in the Carson Valley within a radius of about fifteen miles of the capital of Nevada. The most important spring rises in yellowish sandstone about a mile east of Carson. The temperature of the water is 111 degrees F. A bath-house has been erected at the springs adjoining the State prison. Another hot spring occurs in mica slate 2¼ miles northeast of Carson. The water is clear and has a temperature of 120 degrees F. There are several wells about 10 inches deep in

the ground filled with this thermal water. Both these springs contain sulphereted hydrogen, a gas generally evolved in the fissures of rock in a volcanic region. At Genoa, 14 miles south of Carson, and near Franktown, 10 miles north of the same place, warm springs occur. Both houses and hotels have been built at both these localities. I was unable to learn the temperature of either of these thermal waters. I collected quart bottles full of water from the above springs for analysis, but upon reaching Washington it was found that either the cold weather or careless treatment in transportation had resulted in the breakage of the bottles and consequent loss of contents.

The greater part of the Carson Valley belongs to the Quaternary, and there is very little rock *in situ*, excepting on the eastern side of the valley, where a few minor ridges and buttes of basalt occur. The line of upheaval in these ridges is north and south. Beginning on the north, we have a low range of gray granite, which contains numerous crystals of black hornblende, and separates Washoe Valley from the Carson Valley. Rocky tors of granite outcrop in various places on this divide. The North Carson Mine occurs in this ridge, but for a description of it see chapter on mines. At Swift's Spring, 2½ miles northeast of Carson, a ledge of gray mica slate outcrops. This is the only locality in the valley where a metamorphic rock is found. I did not find the continuation of the mica-slate beds. Olivine incrusts a low ridge of diorite about 50 feet high and a quarter of a mile long in the eastern part of the Carson Valley. A mass of granular yellow sandstone about 30 feet thick outcrops at a point a mile east of Carson. This sandstone is underlaid by clay, and apparently does not cover more than an acre. Invertebrate fossils are common in the rock, particularly the genus *Unio*, which is oftentimes stained by the oxide of iron. Vertebrate remains have also been found, but I was unable to obtain any. Black mica is sparingly disseminated through the sandstone. The rock is extensively quarried by the inmates of the State prison, and is much used for building purposes. The State-house and railway shops of the Virginia and Truckee Railroad are constructed of this sandstone. Buttes of gray basalt, with a porphyritic texture, are found a short distance east and southeast of the State prison. The Como Mountains form the eastern boundary of the Carson Valley. They are composed of trachyte-porphyry. The height of this range is about 8,500 feet.

A bed of soft gray limestone, having a compact texture, occurs near Dayton, and a bed of blue limestone is found near the stage-road about half-way between Carson City and Clear Creek. This rock is burned in kilns at both localities, but I was unable to examine either of the deposits of limestone, and hence cannot state the thickness or dip of the strata.

A bed of lignite occurs about 8 miles due east of the Carson Valley. It lies in the El Dorado Cañon, on the line of Ormsby and Lyon Counties. The locality is known as the Virginia City Company's Coal-mine. A good wagon-road from Dayton renders the mine easy of access.

This lignite was discovered by English miners soon after the finding of the Comstock Lode. Prior to 1865, 9,800 tons of brown coal were exported from the mine, and under the incorporation of 1872, 21,600 tons were taken out, making a total of 31,400 tons since the formal opening of the mine. After 1863 the Virginia City Company suspended work for about eight years. Out of the 31,400 tons which the mine has yielded, 13,800 tons have been burned in Storey County, and the balance at the company's hoisting-works. The amount of money expended since the re-incorporation of 1872 is $110,000, and previous to that time about the same sum, making in round numbers the total cost of working the mine $220,000. I visited this deposit of lignite in the El Dorado Cañon on November 20, 1876, in company with Prof. W. F. Stewart and Mr. R. M. Daggett, the superintendent of the company. The object of our visit was to select a spot for the sinking of a new shaft. After some consultation a locality was decided upon about 1,200 feet southwest of the present hoisting-works. Professor Stewart has described the lignite beds in detail, and I condense from his report the following: "The coal indications in Western Nevada generally appear in the Tertiary. There is reason to believe that the El Dorado lignite belongs to this age. The mine lies near the head of the cañon. There are two shafts, called respectively the Virginia and Newcastle. The former shaft is 420 feet deep, and is the one most used, as the hoisting-works are at the mouth of it, while the latter one is but 85 feet deep and is now full of water. For about 300 feet from the surface the formation consists of alternating layers of marl, soft gray sandstones, shales, fire-clay, carbonized vegetable matter, and beds of weathered lignite. Below this is pudding-stone or bowlder clay, There are three veins of lignite, which are, counting from the surface, respectively 16 feet, 15 feet, and 6 to 8 feet in thickness. Bowlders and volcanic ashes occur between the veins. Pyrite is found with the lignite in the form of cubes. In making a section across the lignite beds from southeast to northwest we have first granite, then the miscellaneous formation containing the veins of lignite, then a dike of basalt, next sedimentary strata referred to the Tertiary, and finally an extensive mass of trachyte, which covers the country for several miles."

SKETCH OF LAKE TAHOE.

Lake Tahoe lies in the heart of the Sierra Nevada, at an elevation of 6,202 feet above the sea-level. It is one of the largest fresh-water lakes in the West, and, unlike many other sheets of water, contains no islands. Lake Tahoe is inclosed by two parallel ranges of grayish granite, called respectively the Eastern and Western Summits.

Lake Tahoe is 21 miles long and 12 miles in the widest part. The breadth, however, varies greatly, the southern portion being much narrower than the northern. The shore-line is very diversified. The numerous bays, rocky promontories, bold headlands, estuaries, and beaches, oftentimes covered with pebbles, remind one of a miniature ocean. Hot springs are found on the north side of Lake Tahoe, near Campbell's hotel. They rise in granite. Standing on the dock in front of the hotel, the observer may see bubbles of gas in several places rising in the clear water of the lake. One spring is inclosed by a brick wall about 3 by 4 feet. The temperature of the water in this spring is 132° F. A bath-house has been built near the hotel directly over another spring, having a temperature of 128° F. The spring-water contains sulphydric acid.

Lake Tahoe is remarkable for its great depth. It is probably the deepest lake in the United States. There are only two lakes in Europe that are deeper than Tahoe, viz: Lago Maggiore and Lago di Como, in Italy. The shallow water has an emerald-green color, which is more frequently observed on the southern and southeastern portions of the lake than elsewhere. The width of the emerald-green zone varies greatly. In some places this zone is nearly half a mile broad, especially in the shallow water of the southern part of the lake. Where the bottom slopes rapidly the emerald-green water extends only 100 to 150 feet from the shore-line. The deep water is of elegant ultramarine-blue color. The transparency of the water is wonderful. According to experiments made by Prof. John Le Conte, a white object can be seen at a depth of 115 feet. The depth of the water at the line of junction of the ultramarine-blue and emerald-green colors is at least 100 feet. The temperature of Lake Tahoe, taken on the north shore in November, is 50° F. This lake does not freeze in winter, and I am inclined to believe that there is but little variation of temperature, if any, throughout the year. The temperature of the deep Alpine lakes is 39°.2 F. at all seasons of the year. People living on the borders of the lake rarely bathe in it, even in midsummer.

Soundings were made in Lake Tahoe in November, 1875, by Messrs. John McKinney and Thomas Jackson, two of the oldest settlers in this section of California. The apparatus used belonged to the Coast Survey, and was forwarded from Oakland, by Prof. Joseph Le Conte. It consists of a hexagonally-shaped plumb attached to a rope about one-quarter inch in diameter. Rhombic pieces of brass are fastened to the rope at intervals of 100 feet. There is a bit of leather half-way between the pieces of brass, and the space between each bit of leather and brass is divided equally by a scrap of red cloth. By means of this apparatus many soundings were taken along the State line, which runs through the middle of the lake, and in the western part of this body of water from Emerald Bay to Observatory Point. The sounding-line was not used at any place east of the State line. Supposing the reader to be familiar with the outline of Lake Tahoe, and beginning at the southern end, the first sounding is 900 feet near the point where the State line trends to the southeast. Going northwards the depth increases steadily. Soundings taken at five localities indicate a depth respectively of 1,385 feet, 1,495 feet, 1,524 feet, 1,600 feet, and 1,645 feet. The average depth of the lake measured along the State line, for 10 miles due north and south, is from 1,200 to 1,410 feet. Commencing on the western shore of the lake, near Emerald Bay, the first sounding is 750 feet. At Rubicon Point, 4 miles further north, the depth is 850 feet near the shore. This is owing to the fact that the face of this rocky headland slants quite abruptly. At Meigs's Bay the depth is 750 feet, at McConnell's it is 700 feet, and Barton's Mills it is 330 feet. A short distance eastward of the two latter places the lake deepens rapidly. Midway between the State line and the shore at McConnell's, the sounding taken was 1,506 feet, and at a point a few miles north, opposite Barton's Mills, the sounding-line marked 1,540 feet. Keeping tolerably near the shore we have 772 feet as the next sounding north of Barton's Mill. The last observations to be mentioned were taken in the northwestern portion of the lake. In front of Tahoe City, the depth was found to be 312 feet; a little further east the sounding-line indicated 1,350 feet, and still further near the State line it is marked 1,504 feet. In general it may be said that while the depth increases in the middle of the lake in going from south to north, it decreases in the same direction in the western portion. In some places the sediment at the bottom adhered to the plumb, and the specimens thus brought up enable us to form some idea of the lake-bed. Near Emerald Bay mica was found in the soundings in considerable quantities, evidently derived from the disintegration of the granitic rocks bordering the lake. But the most interesting sediment was obtained at a point near the deepest part of the lake, 3¼ miles southeast of the Warm Springs, and about 3½ miles northeast of Observatory Point. I have examined this sediment with the microscope and find that it contains many species of Diatoms. Not being very familiar with the protophytes, I sent some of the sediment to Prof. H. L. Smith, of

Geneva, N. Y., for investigation. A few days afterwards Professor Smith informed me that he had identified the following species: *Cyclotella operculata, C. rotula, Pinnularia viridis, Navicula varians, Epithemia turgida, E. sorex, E. argus, E. gibba, E. Westermanii, Gomphonema dichotomum, G. tenellum, G. herculaneum, Himantidium undulatum, Fragilaria capucina, Cocconeis placentula, Navicula elliptica, Cocconema lanceolatum* and varieties, *Mastogloia* ——, *Cymbella* ——, *Celosira undulatum. Melosira italica* is the commonest species. The sediment consists chiefly of it.

Prof. Joseph Le Conte has examined sediment from the bottom of Lake Tahoe. He informs me that a few Diatoms are found at a small depth, while the sediment at great depths consists entirely of Diatoms and certain organic particles, which puzzled him for a long time, as they were much disintegrated. Finally Professor Le Conte recognized this organic matter to be the pollen grains of conifers. They are blown over the lake, sink, and do not decompose on account of the coldness of the water. In closing the chapter on Lake Tahoe I cannot do better than make a brief reference to the appearance of the lake in windy weather. During storms it is not uncommon to see waves 2, 3, and sometimes 4 feet in height. In ordinary weather sufficient motion is imparted to a row-boat to cause sea-sickness. Even on a calm day there is a gentle undulating movement of the water along the lake-coast. During a fresh gale, the waves beat against the shore with almost as much noise and force as on the Atlantic coast. The shore-line is continually shifting, especially on the southern side of the lake, where a sand-beach occurs. Scattered along the coast of Lake Tahoe are numerous pebbles, which are wafted by the waves from place to place as on a sea-beach.

THE EASTERN SUMMIT.

This name has been given to the mountain-range forming the eastern boundary of Lake Tahoe, and extending north and south for about 34 miles. My observations were confined to the portion of the eastern summit lying between Mount Rose and Job's Peaks. The ridge-line of this range is gently undulating, and has a nearly uniform height, there being no lofty pinnacles rising above it. There are but few precipitous gorges in the eastern summit, and the cañons are regular in form, with the exception of Clear Creek Cañon, which is not only very broad and winding, but nearly traverses the entire range. The main stage-road to Glenbrook runs through the bottom of Clear Creek Cañon, and the western part of the road from Carson City through King's Cañon extends along the northern side of this cañon. These roads unite at the summit of the pass, 7,186 feet high, near the toll-gate. From this point a broad wagon-road is continued down the western slope of the range to Glenbrook, a distance of 2¼ miles. There is but one other pass that is traversed by a wagon-road, viz, the pass between Genoa and Kearney's Station. There are several other defiles in the Eastern Summit that can be made practicable for wagons. A wagon-road crosses the range and descends on the western slope to the Virginia tunnel. There is a road running to the head of the cañon due south of Mount Rose. The topographical features of the country would not prevent the prolongation of these two roads across the range to the foot of the western side.

The western slope of the Eastern Summit, like other ranges in the far West, is much steeper than the eastern slope. The entire range is densely wooded, although the timber has been removed on the eastern side. As the method of lumbering practiced here is somewhat peculiar, a description of it may be of interest. On account of the large size of the trees, saws are used instead of axes in felling them. After a tree is cut down, it is sawed into sections about 5 feet long. Deep holes are bored into these sections with a long-shanked auger, into which powder is stored, and the wood is blasted in the same manner as rock. There is no arable land on the eastern slope of the Eastern Summit, except in Clear Creek Cañon, where a few vegetables are raised. There are a few small Alpine lakes on the summit of the range. The Twin Lakes are scarcely worthy of the name, being only 400 by 200 feet in area. Marlette or Silver Lake is about half a square mile in area. This lake is partly artificial, its size having been increased by damming. A tunnel about 8 by 6 feet in cross-section runs out of Marlette Lake. It will be 4,500 feet long when finished and has a southeasterly direction. The waters will be conducted from the east end of the tunnel to the Carson Valley by a flume. The water in the streams of the Eastern Summit is cold and clear. The creeks running down the eastern slope flow through the Carson Plain and empty into the Carson River, while those on the western side of the summit empty into Lake Tahoe. There are no irrigating-ditches in the Eastern Summit, but the waters of several streams are diverted from their natural course and conducted through flumes for the transportation of lumber. The principal flumes in this range are the Clear Creek Cañon, the Franktown, and the Washoe City.

The streams in the Eastern Summit are rapid, narrow, and easily fordable. The soil of the range is largely composed of disintegrated granite. Numerous spurs diverge from the eastern slope of this range, and extend in some cases far out into the plain, appearing like buttresses. There are no spurs on the western slope, unless the head-

lands and points projecting into Lake Tahoe are considered as such. A general account of the topographical features along the eastern border of Lake Tahoe may be appropriately given in connection with the Eastern Summit. Beginning at the northeast corner of the lake we have the semicircular Todman's Bay, which has for the most part a sandy beach. In the northeast corner, black magnetic sand occurs on the shore. For the next 6 miles the banks of the lake are steep, and several low promontories extend from the shore. Just north of Glenbrook a bold rocky headland projects far out from the general shore-line, and forms a very conspicuous point in the northern half of the lake. Glenbrook, the most important settlement on Lake Tahoe, and the headquarters of the lumber trade, lies in a small bay. There is considerable arable-land in this vicinity. A strip of productive land extends back from the lake for a distance of 2 miles, where it is called Spooner's Meadow. Proceeding south the coast-line is quite uniform until Cave Rock is reached. This is a very conspicuous point. The name is derived from the fact that a cave about 20 feet long and 10 feet high occurs on the south side of this projecting rock, which consists of porphyritic trachyte. There are three low, densely wooded tongues of land on the eastern side of Lake Tahoe south of Cave Rock. The shore-line is regular, and sandy for the remaining portion of this coast of the lake. A good wagon-road follows the eastern border of this sheet of water from Glenbrook to Lake Valley. There are no outlying ridges belonging to the Eastern Summit that run parallel to it. The Eastern Summit is bounded on the east by the alluvial valleys of Carson and Washoe. The low ridge of granite that separates these valleys may be regarded as a spur of this main range. There is no other place between Washoe City and Carson City where rock occurs *in situ*.

The Eastern Summit consists chiefly of granite and syenitic granite. A few eruptions of igneous rock have taken place throughout the range. Beginning at the northernmost part of the range explored by me, the first upheaval is Mount Rose, where a conical mass of basalt has broken through the granite. Many bowlders of this rock are scattered over the country for several miles to the east and south. The color of the rock is blue, and on the summit of Mount Rose the basalt is laminated and ferruginous. There are no trees within 300 feet of the top of the peak, the only vegetation being moss and occasional tufts of grass. There are many anticlinal ridges running in every direction on the west of Mount Rose. The rock forming the summit is much disintegrated, and the south side, which is quite steep, is covered with *débris*. This peak is 10,820 feet high. A spur of the Eastern Summit, near Carson, consists of trachyte. On the western side of the range, just south of Glenbrook, a mass of feldspathic diorite, about 700 feet high, occurs. It has been called Shakspeare's Cliff, on account of a peculiar grouping of the lichens on the face of the cliff bearing a strong resemblance to the profile of the poet. The north side of this butte is perpendicular half-way down, with soil and *débris* sloping to the valley. The south side contains many pillars of the diorite, showing the prismatic structure finely. Some of these columns are curved, and of considerable length. Shakspeare's Cliff is 773 feet above Lake Tahoe. The butte known as Cave Rock has already been mentioned. It is about 150 feet high. No igneous rock is found south of this point in the portions of the Eastern Summit explored by me.

The conical mountains known as Job's Peaks and Freel's Peak form the southernmost limit of this range. These peaks, together with their outliers on the north and west, consist of grayish granite. Some of the ridges diverging from Job's Peaks have a serrated outline, and are densely wooded with pine and spruce. The summits of these peaks are covered with loose fragments of granite, while the slopes are dotted with rocky tors and projecting crags, which present a very picturesque appearance. The altitude of these mountains is as follows: Freel's Peak, 10,862 feet; Job's Peak, 10,650 feet; Job's Sister, 10,760 feet. In general, it may be said that the ridge-line of the plateau-like range called the Eastern Summit consists entirely of granite, which is flanked in several places by igneous rocks, which are usually spurs of the range. The average height of the Eastern Summit is about 9,600 feet. Ore-deposits occur in the Eastern Summit, the principal of which are the following:

1. The Montreal mine. This mine is situated about 2¼ miles northwest of Carson City. It was first opened in 1870, and has been worked at intervals ever since. A tunnel, several hundred feet long, has been driven in the side of the mountain, above which is still another tunnel 150 feet in length. The ore occurs in gray granite and quartz rock. The granite is frequently poor in mica. Dark-blue sandstone-veins traverse the country-rock. There is but little water in the mines. The ore is argentiferous; some of it is said to assay as much as $1,700 per ton. The main rock forming the slope of the mountain in which the Montreal mine lies is syenitic granite. A small stamping-mill was in course of erection in September, 1876, and eighteen men were working at that time.

2. The Emerald mine adjoins the preceding. This mine was discovered in 1874, and has been worked at intervals since then. A tunnel 400 feet long has been driven in the granite. The rock is darker within the tunnel than at the surface, where it is soft and crumbling. The ore assays $90 to the ton.

3. The Clear Creek Cañon mine known as the William's Lode. This mine was opened in the autnmu of 1875, and has been worked at intervals from that time. The wall-rock is granite, overlaid by grayish clay. The vein runs north 71° east, and is about 3 feet wide. The dip is 37°. There is a tunnel 300 feet long, and a shaft 75 feet deep has been sunk. The minerals found are malachite, azurite, pyrite, and crystalline-quartz. About $60,000 has been expended on this mine, and but two men were working in September, 1876. Half a mile northward is the Woodstock Lode. The vein-matter runs northeast and southwest, and is exposed in a small prospect-hole. Both the Williams and Woodstock Lodes are argentiferous. There are several other prospect-holes on the ridge between Clear Creek and Carson City, but no developments of any account have been made thus far.

4. The Niagara mine. I did not visit this mine, but the following description is condensed from the report of Mr. H. R. Whitehill for 1873–'74: "The Niagara mine is situated north of King's Cañon, and west of Carson. The vein is incased in slate and gneiss, and is 30 feet wide on the 100-foot level. Besides two cross-cuts on the surface, there is a shaft 5 by 6 feet sunk to the depth of 100 feet. A drift about 70 feet, running in a westerly direction, (the dip of the vein being almost 45° to the west, pitching into the hill,) cuts the vein at about 40 feet, and thence runs 35 feet through the lode toward the west wall. The rock contains from 5 to 30 per cent. of copper, which gives it a green color. The copper schist lies east of the gneiss, in which free gold is found. This mine has good clay walls, and is, doubtless, a true fissure-vein. Assays of ore from this mine have reached into the hundreds. It is incorporated, and is divided into 30,000 shares. The extent of this claim is 1,500 feet along the lode."

THE WESTERN SUMMIT.

This term has been given to the range bordering Lake Tahoe on the west. The portions of it explored in 1876 lie between Pyramid Peak and the town of Truckee, a distance of about 35 miles. The range rises abruptly from the level of the lake to a comparatively narrow serrated ridge-line, and passes gradually into a series of broad plateau-like foot-hills, which extend westward to the Sacramento Valley.

The Western Summit is composed of several ridges running parallel or nearly parallel to each other. Beginning at the southern end, there is the Pyramid Peak Range on the extreme west; then come two minor irregular ridges between it and the Tallac Range. The latter is of a very picturesque outline. The cañons of the Western Summit are winding and greatly diversified. This range is not densely wooded, except along the foot of the slopes, and the peaks are rocky and barren. Quaking-aspens grow on the eastern slope and in Blackwood and Truckee Cañons. There is scarcely any vegetation in the upper parts of the range. Some of the peaks are remarkable for the great variety of lichens growing on their rocky summits. Black, yellow, gray, brown, and red lichens are found on Twin Peaks. White thorn and manzanita bush abound on the easterly side of the Western Summit, and a few ferns are scattered hither and thither. The principal trees are pine, spruce, and fir. In the southern part pines attain the height of 150 feet. The trunks of these trees are oftentimes covered with bright-green moss for a distance of 30 feet from the ground. There is but little arable land in this range; Squaw Valley, Blackwood Cañon, and Tahoe City being the only places where it may be found to any extent. There are numerous lakes on the Western Summit; the most important of which are Fallen Leaf, Cascade, and Echo Lakes. The one first named is situated in the western side of Lake Valley, about 1½ miles from Lake Tahoe, which is 118 feet lower. Fallen Leaf Lake is about 1 mile wide and 3½ miles long. The temperature of the water was 54° F. in October. On the northeast shore of this lake are found pebbles of a great variety of rock, such as slate, basalt, granite, diorite, &c., all of which have been brought from the lofty Western Summit. Cascade Lake is about 1½ miles from Lake Tahoe, and lies directly in front of Tallac Peak; but, unlike Fallen Leaf Lake, its discharge-creek has considerable fall, and the surface of Cascade Lake is 350 feet above Tahoe. A lumber-road leads from the former to the latter.

Echo Lake lies between two rocky ridges on top of the Western Summit, about 1 mile from the Placerville road. It is about 1½ miles long and one-fourth mile broad. The southern bank of the lake is lined with conifers and a few alder bushes. Elsewhere the shores are very barren and rocky. Beside these just-described lakes there are at least twenty others of minor importance throughout the Western Summit. These mountain lakelets usually lie in cup-shaped depressions in the granite.

The principal streams in the Western Summit are the south fork of the American River and the Truckee River. The former rises near the "Devil's Basin," flows south, then southwest, and empties into the Sacramento River. The latter rises at the head of Lake Valley, flows northward through Lake Tahoe, just as the Rhone flows through the Lake of Geneva, then turns westward, and finally, after running northerly for several miles, takes a northeastern direction and empties into Pyramid Lake.

Most of the brooks in this range rise on the ridge-line, flow eastward, and empty into

Lake Tahoe, the more prominent of which are Blackwood and McKinney's Creeks. The water of all these streams is cold and clear.

There are two passes in the Western Summit that are traversable with vehicles: The Placerville stage-road, called the "grade," on the eastern slope, several miles south of Mount Tallac, which was constructed in 1860, soon after the discovery of the Comstock Lode; the other pass that is traversed by a wagon-road is the cañon of the Truckee River, from the town of the same name to Tahoe City. The road runs along the south side of the river for 7 miles from Truckee, when it crosses the stream and continues on the northern shore to the lake. A wagon-road traverses a spur of the Western Summit on the north side of Lake Tahoe, from Warm Springs to Truckee. A road runs up to the head of Blackwood Cañon, which might be continued across the range. A wagon route follows the lake shore from Warm Springs to Tahoe City, and thence to McKinney's. There are no irrigating ditches in this range. The topography of the western shore of Lake Tahoe may be aptly described in the following manner: The southwestern shore of the lake presents bold and rocky headlands. Emerald Bay is an indentation of the coast, extending 2½ miles inward. The opening of the bay is about half a mile broad. Going northward, the shore is tolerably regular, but rises abruptly from the level of the lake. At Rubicon Point a steep rocky promontory juts into the lake. From this place to Tahoe City there is very little rock *in situ*, the shore being a comparatively level strip of alluvium, with a sandy beach, and bordered with a very thick growth of manzanita as far as Sugar Pine Point. The coast-line runs north, without any marked features until Meigs's Bay is reached. This is a picturesque bight, about half a mile in breadth, which is bounded on the north by Sugar Pine Point. This tongue of land is the longest in Lake Tahoe, and covers at least 3 miles in width, including its sinuosities. On the northern side of this point the shore-line trends nearly due west for a mile, and then northward again, without appreciable curves, to Tahoe City, forming the broad Upson's Bay. At this locality the land bears northeast to Observatory Point, a V-shaped cape jutting far out into the lake. The coast-line then runs northerly and curves gradually until it has an eastward bearing, forming the semi-circular Cornelian Bay. The northern shore of the lake tends gently to the southeast until the western boundary of Todman's Bay is reached, thus forming the rocky promontory known as State-line Point, which divides California from Nevada. This point stretches far out into Lake Tahoe, and diminishes gradually in width till the apex consists simply of a row of detached masses of rock, decreasing in size until the water-level is reached.

There has been much more erosion and denudation in the Western than in the Eastern Summit. In the former range the gorges have precipitous walls. The slopes of many ridges are covered with *débris*.

The scenery throughout the Western Summit is exceedingly picturesque. The variety in the landscape seen from any of the high peaks is unique. The rugged mountains azure lakes, and winding cañons present a scene of surpassing grandeur. There is a striking contrast between the eastern and western slopes of this range in reference to the timber; the former being for the most part bare and rocky, while the latter is densely wooded.

There is abundant evidence of the former existence of glaciers in the Western Summit. I have condensed the following extract from Prof. Joseph Le Conte's paper on "Ancient Glaciers of the Sierra,*" as he has studied the glacial phenomena thoroughly:

"Between the Eastern and Western Summits lies a trough fifty miles long, twenty miles wide, and 3,000 to 3,500 feet deep. This trough is Lake Valley. It was formerly occupied by a great glacier rising near Pyramid Peak, filling Lake Tahoe, and escaping northeast toward the plains. Some of the ice escaped by Truckee Cañon, for I have found glacial markings on the rocks in this cañon. During glacial times the trough of Lake Valley, the lower half of which is now filled with the waters of Lake Tahoe, was a great *mer de glace*, receiving tributaries from all directions except the north. The tracks of the smaller glaciers are more easily traced than those of the principal one. Of the two summits, the western is the higher. It bears the most snow now, and in former times gave origin to the grandest glaciers. Again, the peaks on both these summits rise higher and higher as we go toward the upper or southern end of the lake. Hence, the largest glaciers ran into the lake at its southwestern side. Between this point and Sugar Pine Point, a distance of about nine miles, I saw the pathways of five or six glaciers. North of Sugar Pine Point there are also several. They are all marked by moraine ridges running down from the summits and projecting as points into the lake. Inasmuch as the highest mountains are on the southwesterly end of the lake, the greatest glaciers have been there as well as the profoundest glacial sculpturings. I need only name Mount Tallac, Fallen Leaf Lake, Cascade Lake and Emerald Bay. These three fine little lakes, (for Emerald Bay is also almost a lake,) nestled closely against the loftiest peaks on the western summit, are all per-

* Am. Journal, Ser. III, vol. v, p. 125; Proc. Cal. Acad. Sciences, vol. iv, part 5, p. 259.

fect examples of glacial lakes. South of Lake Tahoe extends Lake Valley for fifteen miles as a plain gently rising southward. Its lower end is but a few feet above the lake-surface, and covered with glacial drift modified by water and diversified, particularly on the western side, by *débris* ridges, the moraines of glaciers which continue to flow into the valley or into the lake long after the main glacier had dried up.

"*Fallen Leaf Lake glacier.*—This lake is bordered on either side by an admirably-marked *débris* ridge (moraines) 300 feet high, 4 miles long, and 1¼ to 2 miles apart. These moraines may be traced back to the termination of the rocky ridges that bound the cañon. On the one side the moraine lies wholly on the plain, on the other side its upper part lies against the slope of Mount Tallac. Near the lower end of the lake a somewhat obscure branch ridge comes off from each main ridge, and, curving round, they form an imperfect terminal moraine, through which the outlet of the lake breaks its way. On ascending the cañon, the glaciation is very conspicuous, and becomes more and more beautiful at every step. From Soda Springs upward it is the most splendid I have ever seen. In some places the whole rocky bottom of the cañon is smooth, polished, and gently undulating, like the surface of a glassy but billowy sea. The glaciation is distinct also up the sides of the cañon 1,000 feet above its floor. There can be no doubt, therefore, that a glacier once came down this cañon, filling it 1,000 feet, scooped out Fallen Leaf Lake just where it struck the plain, and changed its angle of slope, and pushed its snout 4 miles out on the level plain nearly to the present shores of Lake Tahoe, dropping its *débris* on either side, and thus forming a bed for itself. In its subsequent retreat it seems to have rested its snout some time at the lower end of Fallen Leaf Lake, and accumulated there an imperfect terminal moraine.

"*Cascade Lake glacier.*—On either side of the creek, running out of this lake from the very border of Lake Tahoe, runs a moraine ridge up to the lake, and thence along each side of it up to the rocky points, which terminate the true mountain cañon above the head of Cascade Lake. I have never anywhere seen more perfectly-defined moraines. I climbed over the larger western moraine and found that it is partly merged into the eastern moraine of Emerald Bay, to form a medial at least 300 feet high and of great breadth. From the surface of the little lake, the curving branches of the main moraine, meeting below the lake to form a terminal moraine, are very distinct. At the head of the lake there is a perpendicular cliff, over which the head of the river precipitates itself, forming a very pretty cascade of 100 feet or more. On ascending the cañon above the head of the lake for several miles I found everywhere above the lip of the precipice, over the whole floor of the cañon, and up the sides 1,000 feet or more, the most perfect glaciation. There cannot be, therefore, the slightest doubt that this is also the pathway of a glacier which once ran into Lake Tahoe. After coming down its steep, rocky bed it precipitated itself over the cliff, scooped out the lake at its foot, and ran on till it bathed its snout in the waters of Lake Tahoe, and probably formed icebergs there. In its subsequent retreat it seems to have dropped more *debris* in its path, and formed a more perfect terminal moraine than did Fallen Leaf Lake glacier.

"*Emerald Bay glacier.*—All that I have said of Fallen Leaf Lake and Cascade Lake applies almost word for word to Emerald Bay. This beautiful bay, almost a lake, has been formed by a glacier. It is also bounded on either side by moraines, which run down to and even project into Lake Tahoe, and may be traced up to the rocky points that form the mouth of the cañon at the head of the bay. Its eastern moraine, as already stated, is partly merged into the western moraine of Cascade Lake to form a huge medial moraine. Its western moraine lies partly against a rocky ridge running down to Lake Tahoe to form Rubicon Point. At the head of the bay, as at the head of Cascade Lake, there is a cliff about 100 feet high, over which the river precipitates itself and forms a fine cascade. Over the lip of this cliff and in the bed of the cañon above, and up the sides of the cliff-like walls, 1,000 feet or more, the most perfect glaciation is found. The only difference between this glacier and the two preceding is that it ran more deeply into the main lake, and the deposits dropped in its retreat did not rise high enough to cut off its little rock basin from that lake, but exists now only as a shallow bar at the mouth of the bay. This bar consists of true moraine matter, *i. e.*, intermingled bowlders and sand, which may be examined through the exquisitely transparent water almost as perfectly as if no water were present. Some of the bowlders are of large size. One sees from the top of Tallac Peak the whole course of these three glaciers, their fountain amphitheaters, their cañon beds, and their lakes inclosed between their moraine arms."

Professor Le Conte has found abundant evidence of the former existence of a great glacier in Lake Valley. Bowlders and pebbles of slate on the north shore of Fallen Leaf Lake can easily be traced to their parent rock in the cañon above the lake. These pebbles have also been traced along the western shores of the great lake beyond Sugar Pine Point to the extreme northwestern shore, nearly thirty miles from their source. The Fallen Leaf Lake glacier was once a tributary to a much greater glacier that filled Lake Tahoe. Again, Le Conte finds additional evidence of a Lake Tahoe *mer de glace* in the contrasted character of the northern and southern shores of the lake. The same

observer states that all the other sierra lakes he has seen certainly owe their origin to glacial agency. Lake Tahoe has been partly shaped by the same operation, and traces of glacial deltas are found along the western shore.

Le Conte thinks careful examination would discover the pathways of glaciers running into the lake from the eastern summit, but he failed to detect any evidences of them. In my own examination of this range I found no traces of glaciers, particularly no glacial scratches. There are some bowlders scattered over the eastern side of the range that may have been transported by glaciers.

The predominating rock in the western summit is granite. But igneous rocks such as basalt, diorite, and phonolite have broken through the granite in several places. This range may be fitly divided into the Pyramid Peak ridge, the Tallac Peak ridge, the Twin Peak ridge, and the ridge north of Truckee Cañon.

Beginning on the south, the Pyramid Peak ridge consists chiefly of granite. This is the westernmost ridge of the western summit, and its southern boundary is the American Fork Cañon, a narrow, windy valley with precipitous sides composed of gray granite. The peak itself is a mass of coarse-grained, yellowish granite, in the form of a pyramid, rising about 300 feet above the ridge-line. The altitude of Pyramid Peak is 10,003 feet. The north side of this peak is much steeper than the other sides. Angular fragments of granite cover the slopes of Pyramid Peak for a distance of a quarter to a half mile from the top. There is a small grass patch on the northeast side of the mountain. The eastern declivity of Pyramid Peak passes gradually into the "Devil's Basin," a vast amphitheater of granite, probably formed by glacial agency, and containing a series of lakelets. A serrated ridge forms the eastern boundary of this basin. The rock is grayish granite, with large, dark specks of the same rock disseminated through it at the point where the Placerville road crosses the western summit. At first sight these spots presented the appearance of hornblende, but on close examination it was found that they were only a darker variety of the granite, although the forms were six-sided. This peculiarity of structure was observed frequently in the southern portion of the western summit. About a mile north of the Placerville road is Echo Lake, (7,478 feet high,) which forms the outlet of a lake-basin extending several miles to the westward. Numerous islands occur in the lakes of this basin, and some of them have a little soil and a few trees. The rock bordering Echo Lake is gray syenitic granite, which is much traversed by joints. On the northeast side of this lake a wall of granite rises abruptly to a height of several hundred feet, and forms the southern end of a mass of the same rock extending north to Gilmore's Cañon.

Although not strictly belonging to the western summit, a brief description of Lake Valley may be given here. The greater part of this valley is Quaternary. There is no rock *in situ* for 4 or 5 miles from Lake Tahoe. A morass covered with coniferous trees extends back from the lake about half a mile, and east and west for a mile and a half. Lake-weed and eel-grass abound in this marsh, where the water varies from 6 inches to 3 feet in depth. Mallard ducks and grebes are common. The sandy beach on the northern side of Lake Valley is lined with alder bushes. About five miles from Rowland's, near Barton's ranch, two buttes of gray granite occur. Black mica, limpid quartz, and grayish-white feldspar are the constituents of the rock. The buttes are several hundred feet in height, and may be considered as outliers of either the western or eastern summits. The country between these buttes is strewed with large granitic bowlders. At the head of Lake Valley, near Hawley's ranch, dark grayish graphite occurs with quartz. A wagon-road runs from Rowland's along the eastern side of Fallen Leaf Lake to Soda Springs, two miles from Gilmore's ranch, on the lake. According to the aneroid, the springs are 325 feet above it. The temperature of the water is 46½° F. The spring-water contains carbonic acid, sesquioxide of iron, and sulphureted hydrogen. It is bottled and sold at Rowland's and other hotels on Lake Tahoe.

The Tallac Peak ridge runs from Gilmore's Cañon to Blackwood Cañon. Between this ridge and that of Pyramid Peak are two minor ridges without any name, composed of many dome-shaped peaks and rocky tors alternating with V-shaped ravines. A vast amphitheater bounds Tallac Peak on the south. The rock is gray granite as far as the springs, where it passes into basalt, having a slaty structure. The creek which flows into Fallen Leaf Lake has cut a small channel in the bottom of this basin, in which are a few cascades. There are several lateral cañons on the south side of Gilmore's Cañon, which rise in rocky terraces one behind another. The western and southern portions of Gilmore's Cañon afford fine examples of *Roches Moutonnées*. The rock is granite on these sides of the cañon and basalt on the northern. A small number of conifers are scattered over the cañon. Mount Tallac is a mass of bluish basalt upheaved through granite. The rock shows nearly every variety of structure known to the members of the basaltic groups. There are both granular and compact species. Some specimens are porphyritic with compact matrix. Incrustations of olivine occur in places. Nearly all the northeast side of Tallac Peak is composed of compact basalt. The wall of rock forming this side rises perpendicularly 700 feet or more from the plateau to the east of it. Three detached masses of rock that have undergone much disintegration project from the face of the main peak. The jointed structure of the basalt has been favorable to

denudation on account of the many fissures in which the water and melted snow freeze, thus expanding the cracks till the rock splits and falls. The difference of hardness in the basalt is well shown in the northeastern side of Mount Tallac. Isolated crags and pinnacles stand out boldly from the mountain, while the rock that formerly connected them with it has been worn away by the influence of the elements. A vast amount of talus lies at the foot of the eastern slope of Tallac. Seeds of the white-thorn and manzanita bush have been scattered over this *débris* and taken root in the rocky soil, thus forming a dense thicket impassable for pack-animals. The southwestern declivity of Tallac Peak slants gradually to Lake Gilmore, and is covered with nutritious grass, together with occasional clusters of trees except for a distance of about 300 feet from the summit. Ledges of blue basalt outcrop in many localities on the southern and western slopes. The height of Tallac Peak is 9,732 feet. Lake Gilmore occupies the bottom of a basin with lofty walls, and is 1,333 feet below the summit of Tallac according to the mercurial barometer. The temperature of the water in this lake is 50° F. The eastern slope of Mount Tallac has been grooved and polished by glaciers. I found fine examples of glacial scratches about half a mile from the summit. In some places the face of the cliff is as smooth as if cut by a chisel. The southern side of this mountain is exceedingly steep, and nearly all of it is covered with rocky *débris*, while a solitary coniferous tree here and there breaks the monotony of the scene. Granite surrounds Tallac Peak on all sides except on the northeast, where Lake Tahoe forms the boundary-line. A description of this mountain would be incomplete without a brief reference to the magnificent view seen from the top. The view is as varied as it is interesting. On the one side the entire range of the western summit is visible, while on the other there is the broad expanse of Tahoe with the eastern summit beyond. Twenty mountain-lakes are in sight. Their mirror-like surfaces, reflecting the blue sky form a pleasant contrast with the somber hues of the densely timbered ridges. The prominent features of the country lying in front of Tallac Peak, as far as Emerald Bay, have already been mentioned. Near the head of this bay is a knob of granite called the Emerald Isle, which is 150 feet high and 300 feet long, and has the shape of a pear. There is a waterfall about 50 feet in height, a quarter of a mile from Mr. Holladay's house. The cañon in which the inlet of Emerald Bay runs is very picturesque. It is narrow, windy, and the walls are very steep. Climbing up the cañon for half a mile from the bay I could catch a glimpse through the clusters of trees of several small cascades. At Emerald Bay and from this point northward the rock is gray granite to Sugar Pine Point. Near Rubicon Point the rock contains red feldspar. There are four more peaks belonging to the Tallac Peak Ridge, the northernmost of which is capped by a sharp granite turret. This feature of peaks culminating in rocky tors occurs elsewhere in the western summit. The ridge becomes very narrow at the head of the creek emptying into Meigs's Bay. From this point to Blackwood Cañon there is no rock *in situ* within from a half to one mile of the lake-shore. The mountain behind McKinney's Station is basalt, and the slopes are covered with a dense growth of white thorn and manzanita. Some mineral indications have been found in the ridge about 1½ miles from McKinney's and 1,000 feet above Lake Tahoe according to the aneroid. The ledge was discovered in July, 1876, and work was begun in September. It is claimed by Messrs. Niles, Bellinger, Sims, and Casey. The vein runs northwest and southeast. In September, 1876, two men were working at an opening in the ledge 7 feet long and 4 feet wide. No analysis has yet been made of the ore, but it is said to contain nickel. On the northeast side of this mountain is Quail Lake, a body of water having an area of about an acre, and 400 feet above Lake Tahoe. Going northward, the rock is chiefly basalt as far as Blackwood Cañon. Blue basalt occurs at the head of this cañon.

The Twin Peak ridge runs from this point north to Truckee Cañon. Twin Peaks are just north of Blackwood Cañon, and consist of basalt and diorite. From the summit of these peaks the observer beholds many V-shaped cañons and serrated ridges. Some of the mountains have the dome structure, some are sharp like a knife-edge, others are conical, or pyramid-shaped or have the forms of a *mesa*. Scattered among these picturesque ridges of granitic and basaltic rocks are a few lonely Alpine lakes in cup-like basins. Twin Peaks are 2,604 feet above Lake Tahoe. West Twin Peak is formed of grayish basalt. The greater part of it is composed of myriads of horizontal prisms averaging about 9 inches in diameter, which decrease in size as the base is approached. At the junction of the East and West Twin Peaks the rock is dark-blue porphyritic basalt with white crystals of feldspar. East Twin Peak consists of gray porous diorite. The whole ridge from Blackwood Cañon to Tahoe City is basalt, of gray and blue colors. Very little granite is found north of this cañon, but south of it as far as Lake Valley, and from 200 to 500 feet from the lake-shore, many bowlders of this rock having a rounded form occur. The cañon of the Truckee River is formed of basalt. At the beginning of the cañon, in leaving Lake Tahoe, the basalt is porous and slightly porphyritic. There is *débris* on the north wall of the cañon, where several crags of basalt outcrop. About a mile from Tahoe City the Truckee River breaks through a mass of pudding-stone basalt, that is slightly ferruginous. Many conifers and some quaking-aspens grow

in the Truckee Cañon, as well as white thorn and manzanita. Six miles from the entrance of the cañon, Squaw Valley is reached. Squaw Creek flows through this valley, which has a broad fertile flood-plain. At the head of the valley there is a steep precipice with rounded bases. The rock is porphyritic diorite. The southern side of Squaw Valley is steeper than the northern. A little farther down the Truckee Cañon is Claraville, the site of an abandoned mining town. Several prospect-holes are seen in the north wall of the cañon. In 1863 a population of 500 people gathered at this point amid great excitement. Soon afterward the mines gave out, and it is difficult now to find the slightest vestiges of a former settlement. The gold occurred in placer-diggings. Beyond Claraville the river takes a northerly course, and the east side of the cañon is blue basalt as far as Truckee. Tors of trachyte 30 feet high outcrop along the western side. Near the fish ranch there is a very irregularly formed butte of gray basalt having a laminated structure. The laminæ are about half an inch thick. The rock on both sides of the cañon has undergone much disintegration. At the town of Truckee coarse-grained gray granite outcrops. It is similar to the rock forming the greater part of the western summit.

The ridge north of Truckee Cañon is the northernmost on the western side of Lake Tahoe. The ridge extends as far as a line drawn through the town of Truckee and Washoe Peak. It consists principally of basalt and phonolite. At Tahoe City a kind of globuliferous basalt occurs on the cliff just north of the post-office. The lower part of it has been eroded by the waves of the lake like a headland on a sea-coast The rock is somewhat ferruginous and much decomposed. It crumbles in the fingers. Near Tahoe City porphyritic granite, containing numerous crystals of white feldspar, is found. Compact bluish granite occurs at Observatory Point, which is a spur of the ridge projecting far into the lake. Beyond this point gray phonolite extends along the lake-shore for 2 miles or more. The remainder of the ridge consists of bluish basalt as far north as Boca, and stretching back from the lake for several miles. Various spurs diverge from this ridge. The crest lines are often dotted with turrets of basalt, and a vast amount of *débris* is strewed over their slopes. Near Wallace's ranch, 5 miles southeast of Truckee, I observed basalt similar to that on Lake Tahoe. A feature worth mentioning in connection with the geology of the Western summit is the absence of sedimentary rocks. No fossils are found by which one can determine the position of these archæan and igneous rocks in the geological series.

In closing a report on the geology of Lake Tahoe and vicinity, a brief reference may be made to the lake as a resort for tourists and pleasure-seekers. Since the completion of the Central Pacific and Virginia and Truckee Railroads, Lake Tahoe has become very accessible. A small steamer, carrying the mail, makes a daily tour of the lake. There is sufficient hotel accommodation for a large number of travelers. Hotels have been erected at the following points on the lake: Hot Springs, Glenbrook, Kearney's, Rowland's, Yanks, McKinney's, and Tahoe City. The finest scenery is found in the southwestern corner of Lake Tahoe, near Tallac Peak. There is no part of the United States that surpasses this region in scenery. In my extensive travels on the continent of Europe I have seen but one lake more picturesque than Tahoe, viz, the lake of Luzerne, in Switzerland. Grace Greenwood, writing from California, says: "Tahoe is the most beautiful lake I have ever beheld. * * * I think Lake Tahoe must yet become a great pleasure resort. I have seen no more charming spot in all my tours for a summer's rest and rambling."

Respectfully submitted.

ALFRED R. CONKLING.

Lieut. G. M. WHEELER,
Corps of Engineers, in charge.

APPENDIX H 1.

REPORT ON THE LITHOLOGY OF PORTIONS OF SOUTHERN COLORADO, AND NORTHERN NEW MEXICO, BY A. R. CONKLING.

NEW YORK CITY, *May* 10, 1877.

SIR: I have the honor to submit herewith a report on the lithology of the portions of Southern Colorado, and Northern New Mexico, explored by me in the field-season of 1875:

The majority of the rocks occurring in this region are of igneous origin. They cover large areas on both sides of the Spanish Range. The most common rocks are dolerite, basalt, granite, trachyte, diorite, granulite, sandstone and limestone. Dolerite occurs more frequently than any other species; vesicular dolerite covers large tracts of country, as in the plateau bounding the San Luis Valley on the west. Compact bluish dolerite is found in the buttes near Costilla post office, New Mexico, and in the mesa northeast of Fort Garland. Olivine is found in the dolerite at several localities. The basalt is usually of a blue color, and varies in texture from compact to scoriaceous.

In some places this rock is incrusted with calcite; and in the amygdaloidal varieties the cavities are occasionally filled with zeolites. Near the head of Uraca Creek, New Mexico, a dark-brown species of scoriaceous basalt occurs having the cavities elongated and very narrow. A gray variety of this rock is found abundantly near Fort Union, New Mexico. The diorite has in general a compact texture, but considerable variety of color. The granite presents great variety in both color and texture. The various colors of this rock observed are gray, red, pink, light and dark shades of blue, and white; reddish granite is the most common, on account of the feldspar of the same color being the predominating constituent. The varieties in texture observed are compact, granular, and porphyritic, and the latter being the most frequent. The granite is generally poor in mica, although a micaceous variety of this rock occurs just west of the Moreno Valley, New Mexico. The feldspar porphyry usually presents great irregularity in the size of the crystals imbedded in the compact matrix. The color of this rock is commonly gray, occasionally inclining to white. The granulite is in general of a reddish color, and granular in texture. Granulite and granite constitute the predominating rocks, in the several mountain ranges from La Veta Pass to Santa Fé. The trachyte presents a compact texture as a rule, and a color varying from light gray to pink. The sandstone is generally of a yellowish color, and has a fine-grained structure. In several localities the rock is ferruginous when the color becomes bright red. Near Costilla peak the sandstone passes into a conglomerate. The fossiliferous sandstones have been described in the geological report. The limestone is usually light blue in color, and of a compact texture. This rock covers a large tract of country in the eastern portion of the area explored in 1875. Besides these rocks may be mentioned clay-slate, and hornblende porphyry, both of which occur in several localities.

The paucity of crystalline schists is remarkable, the only localities being near Uraca Mountain, on Elizabeth Baldy, and on the eastern side of Antelope Creek, in the Wet Mountain Valley. A hard siliceous variety of conglomerate occurs near the top of the sandstone mesa bounding the Vermejo Valley on the west. The matrix of this rock is dark brown, and contains black and white fragments of quartz.

In order to determine with accuracy those rocks having a texture so compact that the constituent minerals could not be recognized with the naked eye, I have made sections of such rocks that were deemed desirable to prepare for microscopic examination. On account of the heterogeneous texture and opacity of some of the specimens of rock, much time and labor have been expended in preparing them. In some cases the brittleness of the rock rendered it impossible to make a section sufficiently thin for microscopic analysis. Such was the case with some specimens of trachyte that were interrupted by fissures. The rock could be ground on the wheel to a certain degree of thinness, after which it invariably crumbled, thus destroying the section. Fifty sections of rock have been prepared by me, and mounted on glass with Canada balsam. The results of my microscopical investigations may be condensed in the following description:

No. 139. Diorite, from Rio Hondo, N. Mex., consisting of white plagioclase, and a few crystals of hornblende. Much olivine, and specks of magnetite occur as accessories.

No. 144. Basalt, from Rio Colorado, N. Mex., containing much disseminated greenish nepheline, pyroxene, and specks of magnetite. The rock is slightly amygdaloidal.

No. 171. Dolerite from Huerfano Butte, Colo., consisting of plagioclase, augite, and much olivine.

No. 173. Nepheline-dolerite from west side of Huerfano Butte, Colo., containing augite, nepheline, and particles of magnetite. The texture of the rock is very compact.

No. 174. Diorite from Cucharas River, Colorado, composed of hornblende and plagioclase. Olivine and magnetite occur as accessories.

No. 190. Syenitic granite from Ute Creek, New Mexico, containing quartz, triclinic feldspar, and a few crystals of mica; black hornblende is abundantly disseminated.

No. 205. Basalt, from near Laughlin's Peak, N. Mex., consisting of nepheline, augite, and some olivine.

No. 206. Dolerite from East Spanish Peak, Colo., made up of plagioclase and pyroxene.

No. 207. Granite from head of Cimarron Creek, New Mexico, composed of reddish orthoclase, grains of quartz, muscovite, and specks of magnetite. A few crystals of a black mineral occur which may be melanite.

No. 208. Syenite, from Cieneguilla Valley, N. Mex., containing plagioclase, hornblende and many grains of quartz.

No. 210. Dolerite, from Rider's Cañon, Colo., composed of plagioclase, many crystals of augite, and specks of magnetite.

No. 211. Diorite, from near Taos Peak, N. Mex., consisting of hornblende, plagioclase, and a few grains of quartz.

No. 216. Dolerite, from San Luis Valley, Cal., containing plagioclase, brownish pyroxene, and a few particles of mica.

No. 217. Dolerite, from Colorado Cañon, N. Mex., consisting of crystals of augite, plagioclase, and specks of magnetite. The rock has a porphyritic structure.

No. 225. Trachyte, from Rosita, Colo., composed chiefly of plagioclase and a little sanidine. A few grains of augite and magnetite also occur.

No. 227. Trachyte, from Taos Range, N. Mex., consisting of sanidine and plagioclase, with streaks of augite and a few specks of magnetite.

No. 229. Trachydolerite, from head of Moreno Valley, N. Mex., including crystals of augite, plagioclase, and irregularly-defined crystals of mica, as well as black specks of magnetite.

No. 233. Dolerite, from San Luis Valley, Colo., containing augite and many crystals of plagioclase.

No. 237. Dolerite, from near Gardner, Colo., consisting of large crystals of augite, plagioclase, and specks of magnetite.

No. 239. Dolerite, from Cerro Blanco, Colo., containing plagioclase and augite.

No. 242. Domite, from Laughlin's Peak, N. Mex., consisting chiefly of plagioclase and a few crystals of augite.

No. 251. Andesite, from East Spanish Peak, Colo., containing plagioclase, a few crystals of pyroxene, specks of magnetite, and dark colored mica.

No. 255. Dolerite, from Comanche Creek, New Mexico, composed of plagioclase, angite, and a few particles of olivine.

No. 258. Dolerite, from Costilla Peak, N. Mex., containing crystals of augite, plagioclase, and specks of magnetite.

No. 259. Dolerite, from East Spanish Peak, N. Mex., consisting of augite and plagioclase.

No. 260. Dolerite, from head of Indian Creek, Colorado, composed of grains and crystals of plagioclase and augite.

No. 261. Dolerite, from South Fork of Cucharas River, Colorado, containing augite, plagioclase, and a green mineral, which is probably olivine.

No. 264. Syenite, from Taos Range, N. Mex., consisting of quartz, crystals of hornblende, plagioclase, and opaque particles that are probably magnetite.

No. 267. Dolerite, from Moreno Valley, N. Mex., containing augite, plagioclase, and specks of magnetite. Pyrite occurs abundantly as an accessory.

No. 268. Quartz, porphyry from ridge of Golconda mine, N. Mex., consisting of plagioclase and quartz.

No. 269. Dolerite, from San Antonio Cañon, N. Mex., containing many microliths of plagioclase, grains of augite, and specks of magnetite.

No. 271. Granite from head of Purgatoire River, Colorado, composed of quartz, oligoclase, and a few crystals of mica, and small particles of an opaque mineral that is probably magnetite.

No. 275. Granite, from Taos Range, N. Mex., containing quartz, orthoclase, mica, and a few grains of hornblende.

No. 288. Rhyolite, from ridge east of Costilla Peak, N. Mex., consisting of plagioclase, some quartz, and crystals of magnetite.

No. 291. Andesite, from Cerro Blanco, Colo., composed chiefly of plagioclase, a few crystals of augite, and many particles of magnetite.

No. 292. Andesite, from Taos Range, N. Mex., containing a few crystals of augite, plagioclase, specks of magnetite, and a little mica.

No. 293. Dolerite, from Colorado Cañon, N. Mex., consisting of plagioclase, many crystals of augite, and some olivine.

No. 294. Dolerite, from Elizabeth Baldy, N. Mex., containing grains of augite, plagioclase, and magnetite.

No. 295. Dolerite, from top of Costilla Peak, N. Mex., composed of plagioclase, augite, olivine, and crystals of magnetite.

No. 298. Diorite, from Costilla Peak, N. Mex., consisting of crystals of hornblende plagioclase, much olivine, and specks of magnetite.

No. 299. Diorite, from Walsenburg, Colo., containing plagioclase, hornblende, and some disseminated mica.

No. 301. Andesite, from Uraca Creek, New Mexico, composed of plagioclase, crystals of augite, and specks of magnetite.

No. 302. Basalt, from tower near head of Cucharas River, Colorado, consisting of nepheline, crystals of angite, and particles of magnetite.

No. 345. Diorite, from a point just west of Laughlin's Peak, N. Mex., containing plagioclase, hornblende, some olivine, and magnetite.

No. 384. Dolerite, from Uraca Creek, New Mexico, comprising augite, plagioclase, and many specks of magnetite.

No. 385. Dolerite, from Rio Grande, New Mexico, containing augite and crystals of plagioclase.

No. 386. Dolerite, from head of Cucharas River, Colorado, made up of crystals of plagioclase, augite, and specks of magnetite.

No. 388. Dolerite, from mesa northeast of Fort Garland, Colo., composed of many fine crystals of plagioclase, and well-defined crystals of augite. This rock resembles closely No. 233. They are not more than 10 miles apart.

No. 394. Dolerite, from Costilla Cañon, N. Mex., consisting of pyroxene and plagioclase.

I have the honor to be, very respectfully, your obedient servant,

ALFRED R. CONKLING.

Lieut. GEORGE M. WHEELER,
Corps of Engineers, in charge.

WASHINGTON, D. C., *June* 30, 1877.

The following manuscript, prepared by Mr. A. R. Conkling, and received too late to be forwarded with the annual report of 1876, is herewith submitted.

GEO. M. WHEELER,
Lieutenant of Engineers.

APPENDIX H 2.

REPORT ON THE FOOT-HILLS FACING THE PLAINS FROM LATITUDE 35° 30′ TO 38° APPROXIMATELY, BY MR. A. R. CONKLING.

Beginning at Las Vegas, New Mexico, which is just east of the foot hills, we have the rolling prairie extending as far as Fort Union, 28 miles northeast, without any marked elevation. The foot-hills on the eastern side of the Las Vegas range consist of grayish sandstone, horizontally stratified. Upon approaching Fort Union broad mesas of moderate elevation lie in front of the foot-hills. These mesas are also composed of sandstone. At the head of the Rio Mora, a grayish mass of eruptive granite has broken through the sandstone. In the vicinity of Fort Union extensive dikes of basalt occur. The western limit of the basalt is, according to my observations, at Torquillo, which lies about 17 miles west of Fort Union. Basalt occurs on the plain lying north of the fort. It covers the surface as far as Ocate Crater, which is just 13 miles north. With the exception of the basaltic lava of Ocate Crater, the basalt is invariably of a dark blue color and scoriaceous texture. Ocate Crater or Mountain is 8,902 feet above the sea-level. It is longer from north to south than from east to west. The summit is bowl-shaped, with the opening on the west side. The slopes, and even the interior of the crater, are covered with grass, while on the northwestern side there is soil enough to support a small growth of piñons and cedars. The northern slopes of the mountain are impassable for animals, but a mule can be ridden to the summit by way of the south side. The land slopes very gradually south of the crater. There is a low butte of basalt on the southwest. The major part of the basaltic lava on the plain of Fort Union has probably come from the Ocate Mountain. There is much variety in the lava of Ocate. The color of the lava varies from bright red to brownish black, and the texture is generally vesicular, though also compact and scoriaceous in some cases. The reddish lava has so many crystals and grains of white leucite disseminated through it as to present a porphyritic structure. Between Ocate Mountain and Fort Union there is a broad and low mesa of basalt, which is bordered on the west by a mesa of gray sandstone. On the southern part of the Fort Union reservation blue limestone outcrops, dipping very slightly to the southwest. Fossil shells, of the genus *Inoceramus*, are found in the limestone, which, according to Professor White, are of cretaceous age. On the ordnance reservation, one mile west of the post, a well has been sunk to the depth of 78 feet. The following section will illustrate the geological structure at this place:

	feet.
Clay	17
Soft yellow sandstone	6
Decomposed lava	6
Basalt	37
Red volcanic scoria	4
Sandstone and gravel	8

The well adjoins Captain Shumaker's quarters.

ORE DEPOSITS NEAR FORT UNION.

There are a few deposits of ore near Fort Union, but none of them are workable. In the Turkey Mountains, about 9 miles from the fort, ground has been broken, where some malachite, or rather rock stained by green carbonate of copper, has been found. There is a single shaft at present, about 30 feet deep, which is partially filled with water. The cupriferous rock occurs in a vein 2½ feet wide at the surface and 6 feet wide at the bottom of the shaft. The lode runs north and south, and occurs in red sandstone. At several other localities ground has been broken in the hope of finding valuable min-

erals, but all without avail. At one time placer-mining was carried on for a few days in one of the gulches of the Turkey Mountains. Gold was found in small quantities amid intense excitement. By the time a large crowd of miners had been collected about the spot the placers gave out. It is my opinion that the gulch was simply "salted." At Coyote, about 14 miles from Fort Union, traces of copper have been found half a mile north of the town. Ore was first discovered here in the summer of 1866. In the same year a mining company was organized with Kit Carson as president and J. B. Collier as vice-president. There was no definite capital, but small personal assessments were made to begin work. There is a vein about 4 feet wide occurring in gray micaceous sandstone, having general direction from northeast to southwest. This vein contains a little malachite and azurite, and is traceable at intervals for the distance of a quarter of a mile. At one point a shaft 22 feet deep has been sunk. At another point, on the ridge near the summit, a slope has been driven about 40 feet in the sandstone rock. Both these places had been abandoned at the time of my visit.

Just east of the plain of Fort Union are the Turkey Mountains. The height of the ridge above the plain is about 700 feet, and the length is perhaps 15 miles. The mountains are composed of grayish sandstone, horizontally stratified, with numerous vertical joints. The ridge runs northwest and southwest, and is much broken up by cañons.

The formation between Fort Union and the Canadian River is both igneous and sedimentary. Directly northeast of the Turkey Mountains a large number of buttes and mesas of basalt occur. Most of the buttes are conical in shape and rounded on top, but a few have the turreted form. Many of the mesas have a perpendicular border of basalt about 10 feet thick, and slopes slanting very gradually on some sides and quite abruptly on the others.

About 15 miles east of the Turkey Mountains limestone outcrops, containing a species of ammonites, which Professor White informs me belongs to the cretaceous. A zone of cretaceous limestone appears to lie between the basalt on the west, and horizontally stratified sandstone on the east. But my observations in this section of country were too limited, by the rapid daily marches, to enable me to define the limits of this zone either on the north or south. Nearing the Canadian River, sandstone again outcrops, containing fossil angiospermous leaves, identical with those occurring in the sandstone near Trinidad, about 65 miles farther north. The Canadian River has cut a channel in the sandstone about 300 feet deep. There is a little soil alongside the river in the bottom of the cañon. The country lying east of the Canadian is a rolling prairie as far as the eye can reach. On the west side of the Canadian the country is much broken up by cañons and ravines, rendering it well-nigh impassable. From the Canadian, our route lay northeast over a rolling prairie, with an occasional low mesa to break the monotony of the plains, until the basaltic country in the vicinity of Laughlin's Peak was reached. Amygdaloidal basalt, with particles of white calcite in the cavities, covers the country on both sides of the Santa Fé road, from a few miles east of the Canadian River to beyond Laughlin's Peak. The geological formation of Laughlin's Peak is peculiar. It is a mass of pinkish trachyte breaking through a plain of basalt. The mountain is 8,949 feet above the sea. The slopes are covered with grass, and the summit has a depression like a crater. Some of the basaltic buttes east of Laughlin's Peak are very perfect in outline. All of them have a moderate height. Sometimes the buttes are altered to ridgy, saddle-shaped hills, a form which volcanic cones have frequently been observed to assume by degradation. There are no lava bombs, lapilli, volcanic sand, or ashes, as in the extinct volcanoes of Central France. The basalt is usually *in situ*. Very little water occurs in this basaltic country. One can travel miles without finding running water, and the only animals seen are occasional herds of antelope that roam over the plain.

On the north side of Laughlin's Peak a mesa-like ridge, with precipitous sides, runs north as far as Trinidad, about 28 miles distant. This is the Raton mesa. On the west side of Laughlin's Peak a hard, grayish slate outcrops, which is overlaid by a bed of loose black shale. The dip of both these rocks is slightly to the southwest. The shale outcrops again at a point about 5 miles west, but I was unable to trace the beds any farther. A narrow dike of basalt has broken through the shale about half a mile from Hole-in-the-Rock. At Hole-in-the-Rock, which by the bye is merely a break in the strata that has been denuded so as to leave a gap, the sandstone with horizontal stratification outcrops again, presenting the same lithological character as the sandstone in the foot-hills a few miles farther west. No fossils were found. The thickness of the exposed strata was not more than 30 feet. On account of the rapid progress through this section of country it was impossible for me to define the limits of the sandstone. Dikes of basalt have in many places broken through and sometimes overlaid this sandstone. Mesas of vesicular basalt cover the country for 15 miles west of Laughlin's Peak. Tenaja Creek has cut a cañon in the mesa, which is known as Bragg's Cañon. On the lower part of Teneja Creek a bed of gray laminated slate outcrops, dipping very gently to the west. Between this creek and the foot-hills of the Cimarron Range the country is rolling prairie without any rock *in situ*. The Canadian River forms the dividing-line between the igneous rock on the east and the sedimentary rock on the west. This refers only to the upper part of the river. The foot-hills from Fort Union

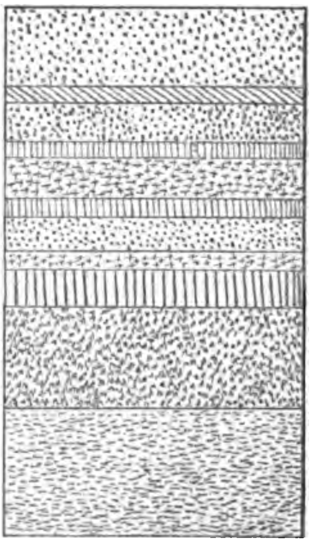
to Cimarron consist of sandstone, except in the vicinity of Uraca Peak, where basalt occurs.

According to De Groat, at the entrance of the Rayado Valley a marly-limestone formation occurs near the basalt. The limestone is suitable for making lime, and it is burned in limekilns built of blocks of basalt. The limestone has also been used for building. In the eastern part of the Maxwell grant the same limestone formation which outcrops at the entrance of the Rayado Valley extends from a point just north of Arnis Ranch to Rock Ranch. The breadth of the limestone is about 8 miles, along the easterly boundary of the grant.

From Cimarron to Trinidad the geology is quite simple. Sandstone, of a color varying from white to gray or yellow, with horizontal stratification, covers this section of country. These foot-hills are densely wooded with conifers and much broken up by cañons. Various creeks, rising in the Cimarron Range, flow through the foot-hills, having cut broad cañons with steep sides. These main cañons have in turn many lateral cañons. At Crow Creek, 12 miles from Red River, some invertebrate fossils were found. A species of *Inoceramus* and a fragment of a shell belonging to the genus *Rudistes* were collected. According to Professor White these fossils are cretaceous. This fact, together with the occurrence of cretaceous fossils at other localities in the foot-hills, indicates that they were formed during the Cretaceous age. Seams of lignite occur in the sandstone at various points. Remains of plants, particularly the leaves of angiospermous trees, are common in the rock where lignite is found. But it is impossible to determine with certainty the age of the lignite-beds without some other guide than these fossil leaves. Prof. J. J. Stevenson, formerly connected with the Geographical and Geological Surveys west of the Hundredth Meridian, has shown that fossil leaves are utterly unreliable in stratigraphical geology. I therefore, in view of the occurrence of invertebrate fossils, feel justified in expressing the opinion that the foot-hills from Fort Union to Trinidad belong to the Cretaceous age. In the vicinity of Trinidad these fossil leaves are very common. A number of specimens were collected, but they have not as yet been determined. It may be stated that among the leaves collected are those of the oak, maple, and poplar.

As regards the beds of lignite mentioned above, no attempt has been made to work any of them, as far as I could ascertain. If limestone occurred in the immediate vicinity of the lignite, the latter could be worked for the purpose of making lime; but as there is no lignite nearer than 50 miles to the limestone, it is evident that it would not be expedient to transport the brown coal such a distance. The lignite is very brittle. In most places it crumbles so easily that it is difficult to collect a specimen that was not in the form of powder.

Several seams of lignite occur on the western side of the Vermejo Cañon. The following section will illustrate their mode of occurrence:



60 feet of sandstone.
3 feet of siliceous conglomerate.
25 feet of yellow sandstone.
1 foot of lignite.
30 feet of limonite or hydrous oxide of iron.
10 feet of lignite.
20 feet of sandstone.
10 feet of limonite.
15 feet of lignite.
75 feet of yellow sandstone.
100 feet of sandstone covered by a sandy soil.

It will be observed that veins of limonite occur in connection with the lignite or brown coal.

A stratum of hard siliceous conglomerate, about 4 feet thick, runs through the sandstone near the top of the mesa, about 6 miles north of Vermejo Post-Office. The rock is fine-grained, and has a brownish color.

Bituminous coal occurs at Trinidad. The outcrops of the coal are either in the Raton plateau, just south of the town, or on the west, 4 miles from the town, on the south bank of the Purgatoire River. The principal deposit of coal occurs at a point 3 miles south of Trinidad, near the Santa Fé road. The vein runs north and south, and has a width varying from 9 to 12 feet, with an average thickness of 5 feet according to the statement of Mr. James, the superintendent of the mine. This vein is traced for a length of 2 miles on the north, and outcrops on the north side of the Raton Mountain. The coal is underlaid by a bed of yellow sandstone. A layer of limonite about 2 feet thick overlies the coal at the place where it is mined. The coal is said to be free from pyrites.

According to Mr. James, there are nine good workable veins of coal in the vicinity of Trinidad, all of which have the same general direction. The coal is mined with the ordinary pick, and carried out in a hand-car running on a tramway. A tunnel about 5 feet wide, and not high enough to allow a man to walk uprightly, has been driven in the mountain to work the coal. This tunnel is about 150 feet long. The coal is sold for $1.50 per ton at the mine. Coke is made and sold for $6 per ton at the mine. The coke is transported in ox-teams to Denver, where it is sold for $19 per ton. At the time of my visit (June, 1875) but three miners were working at the mine. This mineral property is said to be owned by the Denver and Rio Grande Railroad Company. The vein of coal outcropping on the Purgatoire River, 4 miles west of Trinidad. is about 4 feet thick, and underlaid by shaly sandstone destitute of fossils. The coal is some 25 feet above the level of the river. The strata dip gently to the west at this point. But little work has been done at this locality. There are a few abandoned openings of coal. Limonite outcrops on the Santa Fé road within 3 miles of Trinidad, but none of the iron-ores in this vicinity have been worked yet. Labor is cheap and abundant. A writer in the New York Sun states that there are 1,000 square miles of coal in the neighborhood of Trinidad, and now, (1876,) since the Denver and Rio Grande Railroad is completed as far as this town, there appears to be no reason why Eastern and Central Colorado cannot be supplied with coal from Trinidad. As regards the age of this coal I am in doubt. It is either Tertiary or Cretaceous, but which of these I am unable to say.

Fossil leaves are abundant in the sandstone a few miles from Trinidad, but I have already stated that these leaves are not reliable. No invertebrate fossils were found within less than 30 miles from Trinidad. But as the foot-hills on the eastern side of the Spanish Range belong to the Cretaceous age, according to my observations, it is possible that the foot-hills containing the Trinidad coal belong to the same period. However, I am not justified in expressing an opinion on this question.

THE COAL OF THE MAXWELL LAND-GRANT.

What I have written in the succeeding pages about the coal of the Maxwell grant has been translated from the pamphlet of Messrs. De Groot and Leembruggen, published in the Dutch language, at the Hague, in 1874. My imperfect knowledge of this foreign tongue has been a constant drawback to me. Still it is believed that some interesting facts will be found in the translation. It is my opinion that this coal belongs to the Cretaceous age, reasoning from the fact that I have referred the foot-hills in which this coal formation occurs to the same age. I have been unable to find any expression of opinion on the geological age of the coal in the above-mentioned work. I will now quote the principal part of the description of the coal formation given by Messrs. De Groot and Leembruggen:

"The coal formation extends from the Cimarron River northward to the northern boundaries of the grant in the Territory of Colorado. On the west the boundaries of this formation run half a mile east of Ute Creek, along the Poñil Park, Van Bremmer Park, Francisco Pass, and Francisco Park, to the northern limits of the grant. On the east the coal formation is bounded by mesas and by the 'plains,' which are covered with Quaternary deposits as far as the Cimarron River. On this eastern part of the grant the strata of the coal-formation, and the coal-beds occurring therein, lie horizontally, while those beds in the western part which rest on metamorphic rock have a moderate dip of at most 10° to 15° with the horizon. This coal-field appears to have undergone a gentle and slow upheaval.

* * * * * * *

"In the western part of the grant the ridges of hills have a moderate height, the range of mountains is circular, and the valleys, which are likewise circular, pass on both sides gradually into the hills. Faults of minor importance have occurred here. When one enters the valleys from the eastward a large quarry is presented to the eye, wherein the component beds of the coal-formation are exposed in nearly vertical walls. In this locality the valleys are wider, and the dislocations in the strata have been the greatest. Undoubtedly the coal-formation extends under the plains on the east, but within the grant it does not come to the surface, it being covered with alluvium.

"In the southeastern part of the grant, granite and gneiss rocks have been upheaved, which have partly overlaid the westerly edge of the coal-formation, and exerted a favorable influence on the coal occurring therein, but the rocks have also broken through a part of this coal-formation, and overlaid a region 4 or 5 miles broad. In this area the rocks have undergone considerable change, which has resulted in the formation of quartzites, hard shales, clay schist, and sandstone. These metamorphic rocks occur along the western end of the coal-formation, while more westerly the granite and gneiss rocks are found, which were the cause of the metamorphism. We can never say with certainty how far the coal-formation extends outside the limit of the grant, but it is certain that it extends east from the Spanish Peaks, and that coal has been worked within from 2 to 4 miles of Trinidad, in the vicinity of boundaries of the

Maxwell grant. The mesas which occur in the northern and eastern boundaries of the coal-formation consist of basalt, and belong to the Fisher's Peak, a basaltic mountain that has the genuine 'trap' form, and, together with the mesas in the northeastern part of the Maxwell grant, belongs to the Raton Mountains, which, on the northern part of the grant, extend east and west, and continue on the eastward for 26 miles beyond the grant.

"The basaltic mass of the mesas in the northeast part of the grant also outcrops in various little mesas, but it has filled besides many fissures in the coal-formation, and accordingly comes to the surface in dikes. Wherever this has taken place in the coal-formation the basalt has metamorphosed the rock and the coal in the immediate neighborhood. In one place in Red River, 7 miles in the valley above the Red River Station, the basalt has broken through a coal-bed 2 feet thick horizontally, overlying merely a small part of the metamorphosed coal, and where the basalt has destroyed the coal the space is filled with a basaltic mass. This metamorphosed coal is graphite, in some places very pure graphite, that can be developed in order to be used for crucibles, for greasing tools, or for diminishing friction. The basalt has done but little damage in the coal-formation, and it is certain that the rock has been penetrated by the heat developed thereby; it has also co-operated to enhance the good properties of the coal as fuel. The coal-beds outcrop, especially on the western edge of the coal-formation, and likewise in all the valleys of the creeks which run through this formation. There are three localities where the coal-beds have been developed and investigated. A description of them will now be given.

"SECTION IN THE POÑIL VALLEY.

"Three miles from the plains in the Poñil Valley, and 5 miles from Cimarron, about 6,900 feet above sea-level, a section of the coal is exposed on both sides of the Poñil Creek. The coal-bed is 4 feet thick, and consists of pure coal without bands of clay. It is inclosed by 1 foot top-clay and by 2 feet under-clay. The clay and sandstone beds that lie above the coal have sufficient firmness to rest on large openings without caving in, while the quartzose clay sandstone that lies under the coal is a very hard rock that makes an admirable foundation, which never will be exhausted during the working of the coal.

"As regards the properties of the coal of New Mexico, it may be stated that it is particularly fitted for the preparation of coke, for use in generating steam, and for making iron. This coal is also useful for smiths' work. It is less fitted for making gas. In the valley of the Poñil clayey spherosiderite is found, apparently derived from the claystone beds which accompany the coal, whence these lenticular balls of clayey carbonate of iron have occurred in the valley by means of weathering.

"SECTION IN THE VERMEJO VALLEY.

"In a cañon of the Vermejo Valley an important outcrop of the coal-formation is found, wherein occur never less than seven large and small coal-beds, and clayey spherosiderite, in lens-formed balls, as well as clay ironstone, in thin beds. Entering this cañon 3¾ miles in the Vermejo Valley, on the south side, and three-quarters of a mile in the cañon, on the nothwest side, the outcrop is seen. The coal-formation has here a thickness of 200 feet. The coal is always at least 21.5 feet thick. The four lowest beds have sufficient dimensions as to be capable of being developed. The lowest of these beds contains a mass of coal 7 feet thick. In the second bed, counting from below upward, occur two beds of iron-ore, the one being carboniferous and the other argillaceous. Each of these deposits of ore varies from 2.5 to 3 inches thick, and corresponds to the black-band ore of Scotland and South Wales.

"The third and fourth coal-beds have about the same thickness, viz, 3 feet of pure coal, but clayey concretions occur also. A deposit of claystone, 2 feet thick, lies above the fourth coal-bed, in which lens-formed masses of spherosiderite are imbedded. The size of the 'pennystones' of argillaceous iron-ore, which occur in the previously-described beds, varies from very small to 2 feet in diameter and 9½ inches thick. These coal-beds lie horizontally, and are similar in quality to those in the Poñil Valley.

"SECTION IN THE COTTONWOOD CAÑON, RED RIVER.

"In entering the valley of the Red River one sees the coal-formation exposed at a point 4 miles from Red-River Station, (Stockton ranch,) on the south side of the cañon. There is a workable coal-bed 5½ feet thick. This bed is free from claystone concretions, and lies horizontally. The coal has the same good properties as that of the Vermejo and Poñil Valleys. In case railway communication between Cimarron an Fort Lyon and Granada is brought about, the coal at the above-mentioned localities

can be worked advantageously on account of the favorable position it occupies. No shaft needs to be made for the development of the coal. In each of the three localities the coal can be worked by galleries driven into the sides of cañons. As regards the evolution of gas, it may be said that, according to present developments, there is no reason to dread this source of danger. The value of these workable coals is highly important in this region, which is situated so far from the great North American coal-field, and when deep borings shall have been made here the richness of the coals will appear to be much greater than we can safely estimate this wealth at the present time.'

Proceeding north from Trinidad, the country is underlaid by sandstone until the Spanish Peaks are reached. Here dikes of basalt and trachyte-porphyry occur. In Rydar's Cañon a bed of coarse-grained limonite occurs near the wagon-road.

Near the placita of La Molina, a few miles from East Spanish Peak, a dike of basalt occurs, having a height of 25 feet and a width of 5 feet. It runs northeast and southwest, and has broken through the yellow sandstone. As far as my observations go, this is the only basalt near the Spanish Peaks. At Walsenburg and at Fisher's Peak this rock of course is found, but between these places and East Spanish Peak I observed no basalt, except at the locality mentioned above.

In the plain lying northeast of Trinidad a few buttes of basaltic rocks are found. Near the Santa Clara Creek I noticed two buttes of hornblende-porphyry, having a granular texture.

At Walsenburg, on the Cucharas River, a bed of coal occurs. The locality is on the west side of the river. As my visit at Walsenburg was so short, I was unable to examine this deposit of coal, and therefore merely mention the occurrence of the mineral. No attempt had been made to work the coal at that time, (June, 1875) It is possible that this coal may belong to the same age as the coal of Trinidad. There are several low ridges of basalt running north and south near Walsenburg.

Twelve miles east of the town an isolated butte of basaltic rocks occurs in the midst of the plain. It is called the Orphan Peak, or Cerrito del Huerfano. The main part of the butte consists of granular diorite, while on the west side a mass of compact basalt outcrops. This butte is about 200 feet high and 200 yards long. It is longer from north to south than from east to west. These detached masses of igneous rock, lying east of the Spanish Peaks at distances varying from 20 to 25 miles, were evidently upheaved toward the close of the elevation and formation of the main range. Lateral vents existed in the earth's crust through which the basalt was erupted. The numerous dikes of trachyte and hornblende-porphyry on the eastern and northern sides of the Spanish Peaks, and on the eastern side of Sheep Mountain, bear evidence of the vast amount of igneous action that has played a very important part in shaping the physical features of the country. These dikes of rock are in general not more than 100 feet high. They run in all directions, especially in the vicinity of the Spanish Peaks, whence the dikes radiate like the spokes of a wheel. Near the head of Bear Creek two of these walls run at right angles to each other. The country lying east of the Huerfano and north of Badito, which borders on the region traversed by dikes, has been described in the annual report for 1875.

APPENDIX I.

REPORT ON THE ORNITHOLOGY OF PORTIONS OF NEVADA AND CALIFORNIA, BY MR. H. W. HENSHAW.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL SURVEYS WEST OF THE 100TH MERIDIAN,
Washington, D. C., April 15, 1877.

SIR: I have the honor to transmit the following report upon the ornithology of the region visited by me during the field-season of 1876.

Very respectfully, your obedient servant,

H. W. HENSHAW.

Lieut. GEO. M. WHEELER,
Corps of Engineers, in charge.

My opportunities for investigating the bird fauna of this region began in the vicinity of Carson City, Nev., during the last week of August. The rendezvous-camp established here continued till September 15. Up to this date most of my time was occupied in making collections in natural history, such points being visited in the neighborhood of Carson as were accessible by daily trips. The party, in immediate charge of Lieu-

tenant M. M. Macomb, to which I was attached for the season, left Carson on the 15th of September, and from that date till the termination of my field-work, except a period of ten days from November 10 to the 20th, which I spent at Carson, I was occupied in the immediate vicinity of Lake Tahoe, or in the mountains lying contiguous to it. It will thus be seen that the season's results fall under two distinct heads, according as they were obtained in the valleys to the east of and adjoining the main chain, or were derived from observations in the mountains. In presenting lists of the birds observed, with such notes as I was able to gather, I have thus divided them. In connection with my work it is pleasant to be able to speak of the assistance and co-operation so cordially extended to me by the officer in charge, as well as by the remaining members of the party. Furthermore, I have to gratefully acknowledge the substantial assistance received from Mr. H. G. Parker, of Carson City, Nev., not only in the shape of rare birds, the results of his enthusiastic labors, but also for much information concerning the haunts of birds, which his thorough acquaintance with the country enabled him to supply.

By the last week in August such of the birds as still remained in the neighborhood, and which do not winter here, had either congregated in flocks or were in the act of assembling, preparatory for their departure in search of a more congenial winter climate; while not a few of the less hardy species, as the tanagers, orioles, grosbeaks, &c., had already taken their leave; hence a very considerable number of species that are common to the region as summer visitants were not seen at all by us; from which fact it results that our list of the birds noticed during the season is very far from being a complete enumeration of the actual number of species belonging to this region.

The valley, on the west side of which Carson City is situated, does not possess, owing to the almost complete absence of timber, the natural characteristics which serve to attract a great number of species of birds.

Along the banks of the Carson River, and fringing the borders of the other small streams, especially where they debouch from the mountains, is found a limited amount of shrubbery, which serves to invite and give shelter to the species that usually frequent similar localities. The remainder of the valley, not lying close enough to the streams to admit of irrigation and cultivation, is clothed only and everywhere with sage-brush and grease-wood, and is inhabited by but a limited number of the feathered tribe. The foot-hills and eastern faces of the mountains immediately overlooking the Washoe and Carson Valleys were formerly covered with a dense pine forest, which closely hemmed in the valleys. Within a few years this has been entirely swept away, leaving the hills comparatively, and in some places absolutely, denuded of vegetation. As a consequence, most of the wood-loving species that formerly extended down to, or even into, the valleys, have retreated upward, and now only appear below as occasional stragglers, or in winter.

The avifauna of the region about Carson, the mountains being excluded, offers to our notice little or nothing that is peculiar, or that will serve to distinguish it from that much farther to the eastward. In fact, a large proportion of the forms are those common to the interior province generally, of which the entire eastern portion of Nevada may be regarded as an integral part.

It is only when we leave the plains and low open valleys, and ascend into the foot-hills, that we begin to meet with any well-marked change in the aspect of the bird-life. This change is a somewhat abrupt one, and is quite strictly coincident with the line of demarkation between the valleys and the elevated foot-hills, being hence chiefly indicated by the presence of such species as are pre-eminently mountain forms. Thus in the shrubbery skirting the foot-hills, and in the ravines, we find the California jay (*Cyanocitta* var. *californica.*) Reaching the foot-hills the mountain-quail begins to be numerous.* Still higher up the shrubbery of the mountains was found to be the home of the curious Thick-billed sparrow (*Passerella* var. *megaryncha.*) It is, however, in the pine region proper that the change becomes most marked.

Here are found *Turdus ustulatus; Cyanura* var. *frontalis; Selasporus rufus; Sphyrapicus ruber* and *Picus albolarvatus.*

All of the above species are found as regular summer inhabitants of this region, while the woodpeckers and jays are constant residents.

From the occurrence of these species, which may be regarded as belonging essentially to the Pacific province, along this, the eastern slope of the Sierra Range, we may safely draw the line which shall divide the middle from the Pacific province at the foot of the eastern slope of the mountains, and consider this slope of the main chain as belonging, so far as its avian fauna is concerned, to the Pacific province.†

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*As ascertained by Mr. Ridgway, this species is found somewhat farther to the eastward, reaching the mountains by means of the connecting foot-hills. The flocks appear, however, to be little else than stragglers, and with the eastern slope of the main chain this bird ceases to be common, and the species is soon lost altogether.

†Two of the mammals found by us along this slope also point to the same conclusion. The large Spermopilus instead of being the interior form *grammurus* is the *var. beechyie* of the Pacific province. Similarly the small Sciurus is *douglasii* instead of *richardsoni.*

Below is appended a full list of the Pacific province forms that find their eastern limit along the eastern slope of the main chain.*

I. Species limited by eastern slope:

1. *Zonotrichia coronata.* Fall migrant.
2. *Passerella* var. *megaryncha.* Summer resident.
3. *Pipilo* var. *oregonus.* Resident.
4. *Cyanura* var. *frontalis.* Resident
5. *Cyanocitta* var. *californica.* Resident.
6. *Picus albolarvatus.* Resident.
7. *Sphyrapicus ruber.* Resident in small numbers; fall migrant.
8. *Oreortyx picta.* Resident.

II. The following Pacific province species find their limit as above in the breeding season, but during the migrations, especially in the fall, they occur more or less frequently at points at variable distances to the eastward:

1. *Turdus pallasii* var. *nanus.* Migrant.
2. *Turdus swainsoni* var. *ustulatus.* Summer resident.
3. ? *Thryothorus bewickii* var. *spilurus.* Resident.
4. *Troglodytes hyemalis* var. *pacificus.* Winter resident.
5. *Helminthophaga celata* var. *lutescens.* Summer resident.
6. *Myiodioctes pusillus* var. *pileolatus.* Summer resident.
7. *Melospiza melodia* var. *heermanni.* Resident.
8. *Melospiza melodia* var. *guttata.* Perhaps accidental. One specimen in West Humboldt Mountains in fall. (Ridgway.)
9. *Junco oregonus.* Resident.
10. *Zonotrichia leucophrys* var. *intermedia.* Summer.
11. †*Agelaius phœniceus* var. *gubernator.* Summer.
12. †*Nepocætes niger.* Summer.
13. †*Chætura Vauxii.* Summer.
14. *Selasphorus rufa.* Summer.

As noticed above, the fauna of the plains and valleys to the east of the main chain is, in respect to its summer residents, indistinguishable from that of the middle province.

As showing the sharpness with which the line of demarkation is drawn by the Sierra Range we are able to note but two species, which may be considered as characteristically belonging to the middle province, which, in their range westward, intrude beyond the limit assigned and reach into the mountains. These are *Carpodacus frontalis* and *Pica melanoleuca* var. *hudsonica.* The first is numerous about Lake Tahoe, but does not, so far as I could ascertain, reach to the west of the divide. *Pica hudsonica* scarcely finds its way into the range, but is mostly limited by the foot-hills. A few individuals, however, were noticed by us on the borders of Tahoe.

Of the specimens procured along the eastern slope during the season a number have proved of especial interest, as illustrating the differentiation which takes place in a species or variety when found at a point remote from the locality or region where its peculiarities attain their maximum development, and which consequently may be considered its true home.

The eastern slope of the Sierras, though belonging, as has been shown, to the Pacific province, occupies a somewhat intermediate position between the Pacific and Middle provinces, and, as it differs climatically more or less from either region, its birds might be supposed to indicate to some extent, in plumage or otherwise, the changes undergone in the conditions of environment. Such has been found to be true. This is best illustrated in the cases of several birds that are represented by different varieties in the two provinces. In all such instances, while they are seen to partake more largely of the characteristics pertaining to the Pacific forms, they are yet, to a very appreciable extent, intermediate, and, when compared with their respective types from the west coast, will be seen to divaricate directly toward the conditions distinguishing the middle province forms. Thus the Californian jays (*Cyanocitta floridana* var. *californica*) of the eastern slope not only have smaller bills and feet than coast examples, but their colors throughout are decidedly lighter, thus approaching in characteristics the var. *woodhousei* of the interior, which in its typical form begins to occur only in the eastern part of Nevada. Similar differences, though not carried to the same extent, are found in the Steller's jay, in the variety known as var. *frontalis*, which, though confined to the Sierras, becomes somewhat lighter colored, with smaller bill, at its eastern limit than in the Californian coast range on the west.

* For a number of these, as well as for indications of the character of their occurrence, I am indebted to the admirable list of Mr. Ridgway; vide Bull. Essex Institute, vol. 6, No. 10; vol. VII, Nos. 1 and 2; and also in several instances to verbal notes furnished by him.

† These three birds breed in the valleys adjoining the mountains.

The Western Orange-crowned Warbler, (*Helminthophaga celata* var. *lutescens*,) which is distinguished varietally, as it occurs on the west coast, mainly by its brighter coloration, is here decidedly paler, though still approximating more closely to this than to the interior and eastern form, *H. celata*. The same is true of *Myiodioctes pusillus* var. *pileolatus* as compared with *M. pusillus*. The Song Sparrow of this region, though referable to the Pacific type, (*Melospiza melodia* var. *heermanni*,) yet very distinctly approaches the *M.* var. *fallax* of the middle province, and only a short distance to the east of the main chain will be found to merge into the latter. Perhaps, however, in no bird is this tendency toward variation better shown than in the remarkable thick-billed sparrow, (*Passerella iliaca* var. *megaryncha*.) In its typical region, the southern coast range of California, the bill of this bird is enormously developed, till it becomes almost misshapen through its extreme depth. Coincident with this is a change of color, it being several shades darker than its representative from the interior, *P.* var. *schistacea*. Examples from the eastern slope, though unmistakably of this variety, show in the modification of these peculiarities that many steps have been taken toward the *schistacea* form. The colors are lighter; the bill, though still much larger than is ever found in the latter bird, is perhaps scarcely half the size found in extreme examples of *P.* var. *megaryncha*. Other species showing a similar tendency might also be cited, all having the same significance, viz, a differentiation from the typical condition of their respective forms toward the interior type, coincident with their intermediate habitat.

The small number of species of the Warbler family (*Sylvicolidæ*) represented in the Sierra Range, as remarked by us during the season of 1875 in California, and again the past season on the eastern slope, as compared with the number found in the Rocky Mountains, is a matter of much interest. When the comparison is extended to the middle and Pacific provinces proper, nearly the same numerical ratio is found to exist. Noticeable as this is in the cases of these two provinces, when a like comparison is made with the eastern province, a much greater discrepancy in the number of this group is seen. To so great an extent is this true that in a division of the continent into two longitudinal sections this family would enter as a very important factor of the problem, the number of Warblers found in the eastern province, (its divisional line being drawn at about the one-hundredth meridian,) as compared with the western half, being nearly as two to one. No fewer than forty-two species of Warblers inhabit the eastern region. The greater proportion of these occur in the extreme eastern part, being there distributed to the several avian faunas that have been marked out from along its southern border to its northernmost limits. The greatest number of species occur towards its northern portions, especially in the Alleghanian and Canadian faunas as restricted; those whose habitat is northern, visit, of course, the lower faunas in their migrations.

As localities to the westward are noted it will be found that the number of species diminishes, and several birds are lost sight of ere reaching the Mississippi River. On its western edge the eastern province loses quite a large proportion of its characteristic species, no fewer than fourteen which occur along its eastern half, being absent in Kansas. A small percentage of eastern species still persist when the middle province is entered, some of them being found clear across the continent, forming, indeed, the larger percentage of the sylvicoline avi-fauna.

The following is a list of the eastern species that remain when the middle province is reached:

1. *Helminthophaga celata.*
2. *Dendroica æstiva.*
3. *Geothlypis trichas.*
4. *Icteria virens.*
5. *Myiodioctes pusillus.*
6. *Setophaga ruticilla.*

Helminthophaga ruficapilla, *Dendroica coronata*, *D. striata*, *D. maculosa*, and *Seiurus noveboracensis* have all been found more or less numerously in Colorado and elsewhere within the limits of the middle region. They do not, however, breed there, but occur only as migrants in spring or fall as they pass to or from their northern summer haunts within the eastern province; hence they are not included in the above list.

To those enumerated are to be added several species which are characteristic of the middle province, in so far at least as they are not found at all within the limits of the eastern; one or two of these occur, so far as known, only as migrants, their proper habitat being the Pacific province; several are confined to the extreme southern portion of the Rocky Mountains; three only are confined to this province.

The additional species are:

7. *Helminthophaga luciæ.*
8. *Helminthophaga virginiæ.*
9. *Dendroica occidentalis.*
10. *Dendroica townsendi.*
11. *Dendroica nigrescens.*

12. *Dendroica audubonii.*
13. *Dendroica olivacea.*
14. *Dendroica graciæ.*
15. *Geothlypis macgillivrayi.*
16. *Setophaga picta.*
17. *Cardellina rubrifrons.*

Helminthophaga luciæ, *virginiæ*, and *Dendroica graciæ*, are the only ones belonging exclusively to this region.

Of *Dendroica occidentalis*, *townsendii*, and *nigrescens*, the two first come more properly within the Pacific province, as they breed about the Columbia River and Northern Sierras, and only find their way to the Rocky Mountains during the fall migrations, and then to the southern portions of the chain. *Dendroica nigrescens* is equally an inhabitant of both regions. *Dendroica olivacea*, *Setophaga picta*, and *Cardellina rubrifrons* only occur in our territory in Southern Arizona. This portion of that Territory, as well as the corresponding part of New Mexico, faunally considered, belongs with and is indivisible from Northern Mexico.

Leaving the middle region and approaching the Pacific coast, we find that the number of warblers still diminishes, whether we consider the mountains proper, or the low coast regions. In this province we find no species which we have not recognized in one or the other of the two provinces mentioned, though *D. occidentalis* and *D. townsendii* are characteristic of this province as summer residents.

The following is the list:

1. *Helminthophaga ruficapilla.*
2. *Helminthophaga celata* var. *lutescens.*
3. *Dendroica æstiva.*
4. *Dendroica occidentalis.*
5. *Dendroica townsendii.*
6. *Dendroica nigrescens.*
7. *Dendroica coronata?*
8. *Dendroica audubonii.*
9. *Geothlypis trichas.*
10. *Geothlypis macgillivrayi.*
11. *Icteria virens.*
12. *Myiodioctes pusillus* var. *pileolatus.*

Two instances are to be noted here where birds continuing unchanged as they pass from the eastern into the middle province, are in the Pacific region differentiated into varieties, namely, *Helminthophaga* var. *lutescens* and *Myiodioctes* var. *pileolata.*

The evident preponderance of the number of species of this group in the Eastern United States, taken in connection with the fact that so large a proportion of the forms that occur in the western half of the country are eastern species, but little changed, or, as in most instances, actually the same, and that so few are peculiar to that region, seems strongly to favor the assumption that it was in the East that the family had its origin, and that few, perhaps none, of the group were indigenous to the West.

A further consideration of the number of warblers inhabiting the more northern and eastern parts of North America, in comparison with those of the southern parts or Mexico and South America, seems to point to the conclusion that the original center of the family was actually in this (the former) region, and that it radiated out from a comparatively circumscribed area, to become firmly established in and indigenous to the sections where it now flourishes. The Canadian and Hudsonian faunas, as restricted by Allen, receive a larger proportion of warblers in the breeding season than are to be found in any other region of North America of similar extent.

In his geographical distribution of mammals, Wallace arrives at a similar conclusion respecting the *Motacillidæ*, (warblers,) giving their probable origin as North-Temperate America.

LIST OF BIRDS OBSERVED NEAR CARSON CITY, NEV., FROM AUGUST 25 TO SEPTEMBER 16, AND FROM NOVEMBER 10 TO NOVEMBER 20, 1876, WITH NOTES.

TURDIDÆ.

1. *Turdus migratorius*, L., var. *propinquus*, R.—Nevada Robin.

Under the above name Mr. Ridgway has recently described a western variety of the robin, and has indicated certain differences that obtain in the species as it occurs from the eastern base of the Rocky Mountains westward, as compared with examples of the bird from the region east of the Missouri Plains.

The specimens we have seen from Nevada correspond well with his diagnosis of the above bird, and, while we cannot consider the forms in question as illustrating "two

very strongly marked geographical races," they yet appear to be admissible as slight varietal forms.

Apparently not a common species in the valleys during the summer and fall; said to be abundant in the early spring months along the water-courses.

2. *Oreoscoptes montanus* (Towns.).—Sage Thrush.

Fairly numerous amongst the sage-brush. The Sierras appear to limit absolutely the westward range of this species, and it seems to be entirely wanting in California, except in the extreme southern portion, where it reaches across the southern line quite to the coast; so to the northward, where it finds no lofty mountain barriers, it extends to the Columbia River.

SAXICOLIDÆ.

3. *Sialia mexicana*, Sw.—Western Bluebird.

Common.

4. *Sialia arctica*, Sw.—Arctic Bluebird.

Noted about Carson in November, when it frequented the cedar and piñon hills, descending at this season from the mountains, where found earlier.

SYLVIIDÆ.

5. *Regulus calendula*, (L.).—Ruby-crowned Wren.

Quite numerous in the cottonwoods and in the shrubbery of the streams.

PARIDÆ.

6. *Parus montanus*, Gamb.—Mountain Chickadee.

Though, as its name implies, a lover of the mountains, where an inhabitant of the conifers, it yet in fall descends lower, and in the depth of winter is found quite commonly among the deciduous vegetation of the valleys.

TROGLODYTIDÆ.

7. *Troglodytes aëdon*, V., var. *parkmanni* (Aud.).—Parkman's Wren.

Not common; not seen about houses, but frequenting the shrubbery.

8. *Cistothorus palustris*, Wils., var. *paludicola*, Bd.—Long-billed Marsh Wren.

The sedgy margins of Washoe Lake contain thousands of these noisy little wrens, which winter here.

MOTACILLIDÆ.

9. *Anthus ludovicianus* (Gm.).—Titlark.

Not seen about Carson in September, but found on my return in November in small numbers. Found along water-courses, but chiefly in wet, meadowy ground or among stubble.

SYLVICOLIDÆ.

10. *Helminthophaga celata* (Say), var. *lutescens*, Ridgw.—Western Orange-crowned Warbler.

Occurs in small numbers in fall in the shrubbery that skirts the foot-hills.

11. *Dendroica audubonii* (Towns.).—Audubon's Warbler.

Appearing in the valleys only during the migrations.

12. *Geothlypis trichas* (L.).—Maryland Yellowthroat.

A few of this species were seen till into September. They are quite numerous earlier, breeding in the low portions of the valleys.

13. *Myiodioctes pusillus* (Wils.), var. *pileolata*, Ridgw.—Western Black Cap.

One or two seen along the borders of Washoe Lake.

LANIIDÆ.

14. *Collurio borealis* (V.).—Great Northern Shrike.

Makes its appearance about Carson from the north in October. Saw several.

15. *Collurio ludovicianus* (L.), var. *excubitoroides* (Sw.).—Western Loggerhead Shrike.

Appears to be resident in considerable numbers. Quite common in November.

FRINGILLIDÆ.

16. *Carpodacus frontalis* (Say).—House Finch.

Abundant; frequenting especially, and in large flocks, the shrubbery along the Carson River.

17. *Passerculus savanna* (Wils.), var. *alaudinus*, Bon.—Western Savanna Sparrow.

Numerous in wet ground.

18. *Pooecetes gramineus* (Gm.), var. *confinis*, Bd.—Western Grass Finch.

Common among the sage-brush.

19. *Melospiza melodia* (Wils.), var. *heermanni*, Bd.—Heerman's Song Sparrow.

I saw but few of this sparrow in the valleys. It however occurs about Carson, according to Mr. Ridgway, as a common summer resident, and a greater or less number winter.

20. *Poospiza belli* (Cass.), var. *nevadensis*, Ridgw.—Artemisia Sparrow.

The artemisia wastes are peculiarly suited to the habits of this species, and all the year round it may be found in the same localities. It builds its nest in the sage-bush in summer, and as fall approaches the flocks congregate together, not to leave their desolate surroundings, but to wander hither and thither in more extended circles over the same hunting-grounds.

21. *Junco oregonus* (Towns.).—Oregon Snowbird.

In fall and winter numerous in the valleys.

22. *Spizella socialis* (Wils.), var. *arizonæ* (Coues).—Arizona Chipping Sparrow.

Common in summer.

23. *Spizella breweri*, Cass.—Brewer's Sparrow.

Very numerous, inhabiting the sage-brush.

24. *Zonotrichia leucophrys* (Forst.), var. *intermedia*, Ridgw.

This species remains in the mountains till late in the fall, but, gradually descending, becomes by November quite common in the low valleys, where among the brush-wood it remains during the winter.

25. *Chondestes grammaca* (Say).—Lark Finch.

Tolerably numerous. I saw more individuals in November than in August. Frequents at this season for the most part open ground.

26. *Cyanospiza amœna* (Say).—Lazuli Finch.

By the latter part of August nearly all this species had migrated to the south, and only an occasional individual was seen. Numerous in summer.

ICTERIDÆ.

27. *Agelæus phœniceus* (L.).—Red-winged Blackbird.

This is the common species of the marshes about Carson, and of the region generally. This appears to be its western limit. The *A.* var. *gubernator*, according to Mr. Ridgway also occurs in the marshes.

28. *Xanthocephalus icterocephalus* (Bp.).—Yellow-headed Blackbird.

This bird does not appear to be found in any considerable numbers in this locality. They were more or less common in November about the tulle sloughs, and remain during the winter.

29. *Sturnella magna* (L.), var. *neglecta*.—Western Meadow Lark.

Very numerous both in summer and winter, being chiefly found in the pastures, but frequenting to some extent the sage-brush.

30. *Scolecophagus cyanocephalus* (Gm.).—Brewer's Blackbird.

More numerous even than the red-wings, as, too, more generally distributed. In winter they may be seen in almost any situation.

CORVIDÆ.

31. *Corvus corax* L., var. *carnivorus* Bartr.—American Raven.

A common resident.

32. *Gymnokitta cyanocephyala Maxim*.—Blue Crow.

Not an inhabitant of the valleys proper at any season, but often seen in large flocks flying from one range of piñon hills to another. They are resident, and breed among the piñons.

33. *Pica melanoleuca* (L.), var. *hudsonica*, Sab.—Magpie.

The magpie is a very common inhabitant of the valleys, being naturally fond of the densest thickets that fringe the various streams, where they build their nests. The bird plays an important role as a scavenger, and the slaughter-houses form the centers around which all the individuals of a locality congregate.

34. *Cyanocitta floridana* (Bartr.), var. *californica*, Vigors.—Californian Ground Jay.

This species crosses the Sierra range, and is found along the eastern slope of the mountains. It reaches, however, no farther than the foot-hills, but is soon replaced to the east by the closely allied form, the Woodhouse's Jay, (*Cyanocitta*, var. *woodhousei*.) I found it numerous in the brush of the foot-hills; not present in the pine woods of the mountains. By November all had passed farther south.

TYRANNIDÆ.

35. *Tyrannus verticalis*, Say.—Arkansas Flycatcher.

A very abundant species about Carson, where they nest in the shade-trees along the streets. They leave for the south in August, and by the last of the month all had departed.

36. *Sayornis sayus* (Bon.).—Say's Flycatcher.

A single specimen was taken September 8. The species is doubtless a common one during the summer.

ALCEDINIDÆ.

37. *Ceryle alcyon* (L.).—Kingfisher.

Common on all the streams.

CAPRIMULGIDÆ.

38. *Antrostomus nuttalli* (Aud.).—Nuttall's Poorwill.

Present in considerable numbers during summer. The species migrates during the month of September, and is then very frequently started up from among the scrub and brush of the hillsides.

39. *Chordeiles popetue* (Vieill.), var. *henryi*, Cass.—Western Night-Hawk.

Numerous in the valleys. All had disappeared by the last of August.

TROCHILIDÆ.

40. *Selasphorus rufus* (Gmel.).—Rufous-backed Humming Bird.

An occasional individual seen, which had strayed down from the neighboring mountains. Probably not found in the valleys at all in summer.

PICIDÆ.

41. *Picus villosus* (L.), var. *harrisii*, Aud.—Harris's Woodpecker.

Not common in the valleys, but occasionally seen in the trees about Carson in the fall.

42. *Colaptes mexicanus* (Swains.).—Red-shafted Flicker.

Quite common in the valleys in summer; more numerous in fall.

STRIGIDÆ.

43. *Otus vulgaris* (L). var. *wilsonianus* (Less.)—Long-eared Owl.

The only arboreal species that is at all common in the valleys. This bird is very numerous and lives the year round in the little copses of willows and the denser thickets bordering the swampy lands. Their food consists almost exclusively of field-mice, of which they kill vast numbers, a fact which should earn them the protection of the farmers.

44. *Speotyto cunicularia* (Mol.), var. *hypugæa* (Bon.).—Burrowing Owl.

An abundant resident in some of the high pasture lands about Carson, their location being only determined by the presence of suitable burrows made by the several species of ground-squirrels (*Spermophilus.*)

FALCONIDÆ.

45. *Falco communis* Gmel., var. *anatum*, Bon.—Duck Hawk.

In fall making its appearance in considerable numbers along the sloughs and on the borders of the lakes, where it is always ready to capture the water-fowl disabled by the gunners. Its powers of wing are ample to enable it to overtake, in fair pursuit, any of the ducks, and many fall its victims.

46. *Falco sparverius* L.—Sparrow Hawk.

Numerous.

47. *Pandion haliætus* (L.).—var. *carolinensis*, Gmel.—Fish Hawk.

Common on the lakes and streams.

48. *Circus cyaneus* (L.). var. *hudsonius*, L.—Marsh Hawk.

The most abundant of all the predatory birds. Exceeding numerous in the marshes. Never, I think, interfering with the water-fowl, except when wounded, and deriving its subsistence chiefly from the smaller species of rodents.

49. *Buteo borealis* (Gmel.)., var. *calurus*, Cass.—Western Red-tailed Hawk.

Not very common, and seen in the low valleys only in fall and winter.

50. *Archibuteo lagopus* (Brunn.)., var. *sancti-johannis*.—Rough-legged Hawk.

Coming down from the mountains in considerable numbers as fall approaches, and like the Duck Hawk, making its headquarters about the sloughs and open sheets of water. Its chief dependence are mice, but it also seizes many wounded ducks.

51. *Aquila chrysætus* (L.).—Golden Eagle.

Mr. Parker presented me with a specimen of this eagle, which he had killed in the fall near Carson. Its occurrence so low down is not common.

52. *Rhinogryphus aura* (L.).—Red-headed Vulture.

Numerous about Carson, where very useful as a scavenger.

COLUMBIDÆ.

53. *Zenaidura carolinensis* (L.).—Carolina Dove.

Abounds in the low valleys everywhere.

PERDICIDÆ.

54. *Oreortyx picta* (Dougl.).—Mountain Quail.

Scarcely found in the valleys, yet ranging from the high mountains over the foot-hills, and so occasionally met with in the valleys, or at the head of ravines, whither they resort after water.

55. *Lophortyx californicus* (Shaw.).—California Valley Quail.

A few have been introduced about Carson, as I was informed by Mr. Parker. They do not appear to increase at a very rapid rate.

CHARADRIIDÆ.

56. *Aegialitis vocifera* (L.).—Killdeer.

Numerous in summer and fall, becoming rarer as the season advances, and probably but few actually winter in this vicinity.

RECURVIROSTRIDÆ.

57. *Recurvirostra americana*, Gmel.—American Avocet.

Rather abundant during the migrations; many breed about Washoe Lake.

SCOLOPACIDÆ.

58. *Gallinago wilsonii* (Temm.).—Wilson's Snipe.

Not abundant, but still found in considerable numbers, especially during the fall migration. A few doubtless winter.

59. *Ereunetes pusillus* (L.).—Semi palmated Sandpiper.

60. *Totanus melanoleucus* (Gmel.).—Greater Yellowlegs.

Of frequent occurrence in spring and fall, during the migrations.

ARDEIDÆ.

61. *Ardea herodias* L.—Great Blue Heron.

Common.

62. *Herodias egretta* (Gmel.).—Great White Egret.

An occasional individual seen.

63. *Botaurus minor* Gmel.—Bittern.

Very common in the marshes.

RALLIDÆ.

64. *Rallus virginianus* L.—Virginia Rail.

Rather numerous.

The *Porzana carolina* was not seen by us, but was found by Mr. Ridgway breeding in the Truckee Valley, and doubtless it is found in all the marshes of this vicinity.

65. *Fulica americana* Gm.—Coot.

Breeds in great numbers in the tules of Washoe and other lakes of this region. In fall appears in immense numbers.

ANATIDÆ.

66. *Cygnus buccinator* Richardson.—Trumpeter Swan.

Mr. Parker informed me that occasionally a swan strayed on to Washoe Lake. At the sink of the Carson River this swan is found in fall in very great numbers.

67. *Anser hyperboreus* Pall.—Snow Goose.

Coming from the north in large flocks in October and November.

68. *Branta canadensis* (L.).—Canada Goose.

Migrants from the north appear in the fall in large flocks; some merely make a temporary sojourn, and continue their course southward. Many of those arriving late remain about the lakes all winter.

69. *Branta canadensis* (L.), var. *leucopareia* (Brandt).—White-collared Goose.

A single individual of the above variety, one of a small flock, was shot in November by my friend Mr. Parker. The three forms of the Canada goose (*canadensis, hutchinsii,* and *leucopareia*) appear to come from the north in associate bands, the flocks being often composed in this locality of varying numbers of either bird.

70. *Dendrocygna fulva* (Gm.) Burm.—Fulvous Tree Duck.

With a habitat extending far down into Central and South America, this duck yet occurs along our southern borders, and it is probable with greater regularity and in more considerable numbers than the isolated records of its capture would seem to imply. A specimen is in the Smithsonian from New Orleans, and the species was found at the mouth of the Colorado River by Dr. Palmer. It was detected at Fort Tejon, Southern California, by Xantus, while as high up as San Francisco it seems to be of not very unusual occurrence.

To the notices above is to be added the fact of its occurrence at Washoe Lake, Nevada, where the species was found by my friend Mr. Parker in the early part of this year (1877). He succeeded in shooting three out of several large flocks, one of which specimens is now before me. As this neighborhood is almost destitute of trees, it is certain they do not spend the summer here, but probably pass on to some of the heavily-timbered valleys, as the Lower Truckee, which would appear well adapted to their peculiar arboreal habits. Their occurrence here may, however, be somewhat of an accidental nature, as Mr. Parker writes that they were seemingly driven in with myriads of other fowl by a severe snow-storm, and that neither himself nor any of the gunners of that vicinity had ever seen them about the lake before. Notwithstanding which fact, it is by no means unlikely that future investigations will show the bird to be a regular summer resident of such portions of this region as are suited to its needs.

71. *Anas boschas* L.—Mallard.

A common summer resident; very abundant in fall and winter.

72. *Dafila acuta* L.—Pintail.

Most abundant in the late fall, when, with other species, it appears from farther north.

73. *Chaulelasmus streperus* (L.).—Gadwall.

Breeds commonly, and in fall is numerically one of the best represented of the family.

74. *Mareca americana* (Gm.).—Baldpate.

Very numerous, especially late in fall.

75. *Querquedula carolinensis* (Gm.).—Green-winged Teal.

Very numerous. Is in August and early September perhaps the most numerously represented of any of the family.

76. *Querquedula discors* (L.).—Blue-winged Teal.

Not nearly so common as either of the other two species.

77. *Querquedula cyanoptera* (V.).—Red-breasted Teal.

It breeds in great numbers in the region generally. I believe it migrates south earlier than any other species. I failed to detect its presence in November, and think none remain to winter.

78. *Spatula clypeata* (L.).—Shoveller.

Very abundant, both as a summer resident and a fall migrant.

79. *Aix sponsa* (L.).—Summer Duck.

Rather uncommon.

80. *Fuligula marila* (L.).—Greater Blackhead.

One of the later arrivals in fall from the north. Abundant.

81. *Fuligula marila* (L.), var. *affinis*, Eyton.—Lesser Blackhead.

Like the preceding.

82. *Fuligula collaris* (Donovan).—Ring-necked Duck.

Breeds abundantly in the various lakes. I found the young as late as September 3 still unable to fly.

83. *Fuligula ferina* (L.), var. *americana* (Eyton).—Redhead.

Present in the fall, but never, I think, in great numbers.

84. *Fuligula vallisneria* (Wils.).—Canvas-back.

Was told by Mr. Parker that he had shot quite a number of this species about Washoe Lake.

85. *Bucephala albeola* (L.).—Buffle-headed Duck.

In considerable numbers in fall.

86. *Mergus serrator* (L.).—Red-breasted Merganser.

Numerous.

87. *Mergus cucullatus* (L.).—Hooded Merganser.

Quite abundant, but occurring late in fall.

88. *Erismatura rubida* (Wils.).—Ruddy Duck.

Apparently not very common.

PELECANIDÆ.

89. *Pelecanus trachyrynchus* Lath.—White Pelican.

Only appearing on Washoe Lake in fall, and in small numbers. Said to breed in great numbers on Pyramid Lake, to the north.

GRACULIDÆ.

90. *Graculus dilophus* (Sw.).—Double-crested Cormorant.

This cormorant is found on the various lakes in summer.

LARIDÆ.

91. *Larus delawarensis* Ord.—Ring-billed Gull.

This gull was found in great numbers on Washoe Lake in September and October. During the fall its distribution throughout this region is very general, and wherever found it is abundant.

92. *Larus californicus* Lawr.—Californian Gull.

Mingled with the preceding were a few of this species or variety.

The relationship of these two birds appears not to be thoroughly established yet, and in a series of eight specimens from Washoe and Tahoe Lakes, I find several in the immature plumage which I assign with difficulty. In adult plumage the present bird is said to have a larger bill than the preceding species, and to present some distinctive points of coloration, especially in its darker mantle. The only adult bird I have agrees well with the diagnosis, but in the case of the immature plumage there appear to be no thoroughly reliable distinctive characteristics which will serve to distinguish the two species.

93. *Sterna regia* Gambel.—Royal Tern.

Found on Washoe Lake in small numbers late in the fall.

94. *Hydrochelidon fissipes* (L.).—Black Tern.

Seen in small numbers on Washoe Lake in August. None were present in November.

COLYMBIDÆ.

95. *Colymbus torquatus* Brunn.—Great Northern Diver.

Present on Washoe Lake in November, where I saw two individuals. Was informed, however, that its occurrence here was unusual. Its dispersion over all portions of the west in fall and winter appears to be general.

PODICIPIDÆ.

96. *Podiceps* (*Æchmophorus*) *occidentalis* Lawr.—Western Grebe.

Breeds abundantly in Washoe Lake. The young still in the down were taken August 31. One of the main subgeneric characters of this bird is the absence of colored ruffs or other nuptial ornaments about the head during the breeding season, it thus forming a striking exception to the general rule obtaining in the family. The young, the first I believe ever taken, are now before me, from the above locality. They scarcely need description, more than that conveyed in the general statement that in the distribution of colors they almost exactly resemble the old birds. In this respect they seem to carry out the peculiarities of their parents, inasmuch as the young of the other grebes are all, so far as I am aware, curiously streaked or mottled in their first or downy plumage.

LIST OF BIRDS OBSERVED ON THE EASTERN SLOPE OF THE SIERRAS, NEAR CARSON CITY, NEVADA, FROM SEPT. 16 TO NOV. 7; WITH NOTES.

TURDIDÆ.

1. *Turdus migratorius* L., var. *propinquus* Ridgw.—Nevada Robin.

During the month of September the Robins began to be rather numerous along the mountain sides, the number of those resident here during the summer having doubtless been increased by the arrival of birds reared farther to the north, while they were rendered more conspicuous from the fact of their having flocked. In early November they were seen in great flocks at different localities, where were found various kinds of wild berries. The majority of these birds, if not all, pass farther south to winter.

2. *Turdus nævius* Gm.—Varied Thrush.

A male of this species which I saw confined in a cage in a store in Carson City was said by the owner to have been captured during the previous spring in the adjoining mountains. For this statement I cannot vouch, but give it for what it is worth. This thrush has never been recorded from any locality east of the Sierras; yet there seems to be no reason why during the migrations, as in the case of other birds possessing a similar summer habitat, the species may not occur along the eastern slope. That it actually does so, however, remains to be proven.

SAXICOLIDÆ.

3. *Sialia mexicana* Sw.—Mexican Bluebird.

During the month of September and early October this species was rather numerous among the pines at an elevation of about 7,000 feet. After this fewer were seen, a partial emigration having perhaps taken place, or, as is more likely, the species having retired from the high altitudes to the valleys, where they winter in considerable numbers.

4. *Sialia arctica* Sw.—Arctic Bluebird.

At the time the preceding species began to diminish in numbers the present bird attracted attention by a corresponding increase, and it soon almost wholly represented the other in the mountain region. They winter among the pines and in the brushy ravines, forming a close association with the Titmice, Nuthatches, etc.

SYLVIIDÆ.

5. *Regulus calendula* (L.).—Ruby-crowned Kinglet.

Abundant during the fall months among the pines, sometimes in small companies of their own species, but more often distributing themselves by twos and threes among the flocks of winter birds.

PARIDÆ.

6. *Lophophanes inornatus* (Gamb.).—Plain Titmouse.

A resident, but not very numerous. Inclined to favor with its presence the cedar and piñon hills rather than the pine region proper, from which, however, it is not entirely absent.

7. *Parus montanus* (Gamb.).—Mountain Chickadee.

Appears to be the only other representative of the family in this region. A constant resident of the pineries.

SITTIDÆ.

8. *Sitta carolinensis* Gm.; var. *aculeata*, Cass.—Slender-billed Nuthatch.

An abundant resident of the pine timber.

9. *Sitta pygmæa* Vig.—Pygmy Nuthatch.

The most abundant of the tribe, keeping exclusively in the pines, among which they wander in large flocks.

CERTHIIDÆ.

10. *Certhia familiaris* L., var. *americana*, Bon.—American Creeper.

Only a few seen, and these among the pines.

SYLVICOLIDÆ.

11. *Helminthophaga celata* Say, var. *lutescens* Ridgw.—Western Orange-crowned Warbler.

This variety was found rather common during September about Lake Tahoe, frequenting chiefly the brushy thickets on the mountain sides. It probably breeds all along the eastern slope.

12. *Dendroica audubonii* (Towns.).—Audubon's Warbler.

The only numerously represented species of the family. Not, I think, nearly as abundant as in the Rocky Mountains at the corresponding season. Keeping generally in the pines, but also seizing much of its food from the ground.

TANAGRIDÆ.

13. *Pyranga ludoviciana* (Wils.).—Louisiana Tanager.

A very much belated individual of this species was seen September 18. The species had passed south long before.

AMPELIDÆ.

14. *Myiadestes townsendii* (Aud.).—Townsend's Solitaire.

None seen till the first days of October; after this, small companies were occasionally noted in various localities through the mountains. Probably more or less pass the summer on the higher summits.

FRINGILLIDÆ.

15. *Carpodacus cassini* Bd.—Cassin's Purple Finch.

In September this Finch was not uncommon about Lake Tahoe. After which none were seen, the species having migrated. It is a summer resident in this region.

16. *Melospiza melodia* var. *heermannii* (Bd.).—Heermann's Song Sparrow.

Quite rare among the mountains. Occasionally one seen in October in the thickets along the streams.

All examples of the Song Sparrow I have seen from this region, while referable to the above variety, yet mark quite a decided step in the advance towards the central region form, the *M.* var. *fallax*. They are not so dark colored as specimens from the California coast, and the bills appear to be somewhat slenderer, approximating in these particulars to *fallax*.

17. *Junco oregonus* (Towns.).—Oregon Snowbird.

Very abundant everywhere. I presume this hardy species winters in the mountains: at least many remain till the snow falls to a considerable depth.

18. *Zonotrichia leucoprys* (Forst.), var. *intermedia* Ridgw.—Western White-crowned Sparrow.

This bird was found by Mr. Ridgway breeding abundantly on the eastern slope. It

is found all over the mountains, and in fall crosses the range, and is found but little less abundantly in Southern California.

NOTE.—The *Zonotrichia leucophrys*, though not noted by us, doubtless occurs mingled with flocks of the above bird, especially as it was found by us in Southern California.

19. *Zonotrichia coronata* (Pall.).—Golden-crowned Sparrow.

The great mass of these sparrows, in their journey southward, keeps on the western slope of the Sierras. It occurs, too, along the eastern spurs in fall, but, comparatively speaking, in very small numbers.

20. *Passerella iliaca* (Merr), var. *megaryncha* Bd.—Thick-billed Sparrow.

This appears to be the only Passerella occurring along the eastern slope, where it is numerous in summer and fall, and where I believe it is resident.

In a recent report (1876) I was led to combine the present bird with *P. schistacea*, separating them from the *P. townsendi* and *iliaca* mainly on the strength of the different proportions. Subsequent examination, however, has convinced me that the genus is represented by but one species, and that the three western forms, *townsendi*, *schistacea*, and *megaryncha* are but varieties of one and the same species. These under different conditions of climate have become more or less differentiated from the original type till they represent well-marked geographical races, the intergradation of which with each other and with *iliaca* it is perfectly possible to show. As noticed in an earlier part of this report, all specimens of the variety *megaryncha* from the eastern slope of the Sierras show very decided intermediate characters between the extreme condition this form assumes in the Coast Range and the *P. schistacea* from the interior, a fact to be expected from the half-way position of the region. A series connecting the two may very readily be formed. An examination of the material in the Smithsonian, much of which was collected by the expedition, enables us to speak with equal confidence of the close relationship existing between *schistacea* and *townsendi*. Specimens connecting the two in a very complete chain may easily be selected. Hitherto no specimens intermediate between *iliaca* and *townsendi* have been met with, and though the differences separating them have been chiefly modifications of color only, differences of degree of intensity and not of pattern, this has been deemed sufficient to keep them apart.

It will be remembered that the habitats of the two are, in the northwest, in close juxtaposition to each other, *iliaca* being one of quite a number of eastern birds that in the north find their way across the continent and reach Alaska. *Townsendi*, with its summer home in the northern portion of the Pacific province, also reaches Alaska, and it is probable that here the two forms come together. At all events, a series of sixteen specimens collected by the expedition in California, in 1875, presents unquestionable evidence of the intergradation of the two. Of these I do not find one which compares exactly with the usual style of *townsendi*, as it appears in specimens from Kodiak, Sitka, etc. The one extreme of this series exhibits quite a close approach to the dark olive-brown of *townsendi*, with its unstreaked dorsum; the other in its light condition quite suggests the ferruginous style of coloration of *iliaca*; such specimens have the back obsoletely streaked. One other specimen from California in the Institution so closely approaches *iliaca* that it was so labeled, and supposed in the absence of others showing its true relation to be a straggler of this species. In connection with the above suite its position as one of the series showing the intergradation of the two forms is readily seen.

The following measurements illustrate the relations, in size, the four forms bear to each other:

P. iliaca: Wing, 3.40; tail, 3.07; bill, .32; tarsus, .93; (average of ten specimens.)

P. townsendi: Wing, 3.20; tail, 3.15; bill, .49; tarsus, .94; (average of twenty-three specimens.)

P. schistacea: Wing, 3.13; tail, 3.37; bill, .44; tarsus, .91; (average of nine specimens.)

P. megaryncha: Wing, 3.21; tail, 3.58; bill, .51; tarsus, .93; (average of eight specimens.)

As will be seen from the above measurements, *schistacea* and *megaryncha* agree in having the tail considerably in excess of the wing; while in *iliaca* and *townsendi* the wing exceeds the tail. In *townsendi*, however, this discrepancy in favor of the wing is very slight, and, indeed, in some few specimens the two are equal, or the tail may even be slightly in excess of the wing. It would appear, therefore, that in respect to the relative size of these parts, *townsendi* indicates the first step in the variation, which is seen to be more marked in *schistacea*, and to find the limit in *megaryncha*.

One unexpected fact shown by these measurements is, that not only does an increase in length of tail take place in the three western varieties, a variation shown in other species, whose habitat extends from the eastern into the western province, but a decrease in size of wing. The different proportions which ensue come, then, from two

causes: first, actual increase in the length of the tail; second, actual decrease in the length of the wing.

By the above arrangement the four forms will stand as follows:

Passerella iliaca (Merr.).—Habitat: Eastern province of North America; breeds from British America northward, across to mouth of Youkon. In migrations to eastern edge of great plains; occasional in spring in Colorado (Maxwell) fide Ridgway.

Passerella iliaca, var. *schistacea* Bd.—Habitat: Middle province; restricted by western edge of plains and eastern slope of Sierras; an occasional straggler in Kansas and California in fall.

Passerella iliaca, var. *townsendi* (Aud.).—Habitat: Pacific province; breeds in northern Sierras; Southern California in winter; confined to western slope of Sierras.

Passerella iliaca, var. *megaryncha* Bd.—Habitat: Southern Sierras, eastern as well as western slope; probably a resident species.

21. *Pipilo maculatus* (Sw.), var. *megalonyx* Bell.—Long-spurred Towhee.

I saw but few Pipilos, and these on the brushy foot-hills, or in the chaparral of the mountain sides. They were extremely shy, so much so that I failed to secure specimens. They were doubtless of the above variety, as the variety *oregonus* is a more northern form.

22. *Pipilo chlorurus* (Towns.).—Green-tailed Finch.

Not uncommon in October; probably rather numerous in summer.

ICTERIDÆ.

23. *Scolecophagus cyanocephalus* (Wagl.).—Brewer's Blackbird.

Rather numerous during the fall months on the borders of Lake Tahoe.

CORVIDÆ.

24. *Corvus corax* L.—Raven.

Not nearly so common in the mountains as in the valleys below.

25. *Picicorvus columbianus* (Wils.).—Clarke's Crow.

A very abundant resident throughout the pine-region, appearing to live exclusively upon the pine-seeds.

26. *Pica melanoleuca* L., var. *hudsonica* (Sab.).—American Magpie.

As noticed in the previous list, scarcely reaching into the mountains, and but few were seen on the immediate borders of Lake Tahoe.

27. *Cyanura stelleri* Gm., var. *frontalis* Ridg.—Blue-fronted Jay.

Very abundant on the eastern slope, here replacing the var. *macrolopha* of the Rocky Mountains. A permanent resident.

TYRANNIDÆ.

28. *Empidonax hammondi* (Xantus).—Hammond's Fly-catcher.

This was the sole representative of the family noted by us in the mountains. It probably is not uncommon as a summer resident.

CAPRIMULGIDÆ.

29. *Antrostomus nuttalli* (Aud.).—Nuttall's Poorwill.

Not uncommon in fall in the shrubbery of the open mountain sides, but avoids the pine-woods.

TROCHILIDÆ.

30. *Selasphorus rufus* (Gm.).—Rufous-backed Humming-bird.

The only humming-bird seen by us in the mountains. Very numerous in September and the first of October.

An unaccountable fact to us in connection with the present bird is the apparent absence of all adult males in the fall from localities and regions where the young and fe-

males abound. In the fall of 1875, while in Southern California, we failed to find a single adult male in the valleys, although the species was very numerously represented by adults of the other sex and by the young. The absence of the males was attributed to the fact of their having found their way into the mountains, though this seemed a hardly adequate explanation. The experience of the past season was but a repetition of that of the previous year, except that our ground of observation was exchanged for the mountains. Where females and young were to be seen by scores, a most careful search failed to discover a single adult male.

Mr. Ridgway, we learn, had a similar experience in fall along the eastern slope, and was equally at a loss to understand whither the males had betaken themselves.

ALCEDINIDÆ.

31. *Ceryle alcyon* (L.).—Belted Kingfisher.

Present on the shores of Lake Tahoe in small numbers, as on the small streams.

PICIDÆ.

32. *Picus albolarvatus* (Cass).—White-headed Woodpecker.

Numerous in the pine-woods, to which it strictly confines itself, and where it is resident.

33. *Picus villosus* (L.), var. *harrisii* Aud.—Harris's Woodpecker.

Perhaps the most numerously represented in the mountains of any of the family where resident, but not confining itself so closely to the pineries as the preceding bird.

34. *Picoides arcticus* (Sw.).—Arctic Woodpecker.

This species appears to be of rather common occurrence about Lake Tahoe, where I saw it occasionally in September, October, and November. It, without doubt, breeds here.

35. *Sphyrapicus ruber* (Gm.).—Red-breasted Woodpecker.

Apparently not very common. Probably a few breed along the eastern slope.

36. *Sphyrapicus thyroideus* (Cass).—Brown-headed Woodpecker.

Not at all uncommon in the pine-woods about Lake Tahoe, where it breeds and is a constant resident.

37. *Asyndesmus torquatus* (Wils.).—Lewis's Woodpecker.

I saw but few of this species. It is probably a summer resident, and does not winter in the region.

38. *Colaptes mexicanus* (L.).

Numerous; less so, however, in the mountains than in the valleys below.

STRIGIDÆ.

39. *Bubo virginianus* (Gm.), var. *arcticus* (Sw.).—Western Horned Owl.

Abundant; its hooting heard at every camp.

40. *Otus vulgaris* (L.), var. *wilsonianus* (Less.).—Long-eared Owl.

Common in the thickets of the meadowy lands bordering upon Lake Tahoe.

FALCONIDÆ.

41. *Falco communis* Gmel., var. *anatum* Bon.—Duck Hawk.

Met with frequently in early fall. Probably this species leaves the mountains when severe weather comes on and winters in the valleys. At all events it becomes quite common in the lower regions in November.

42. *Pandion haliætus* L., var. *carolinensis* Gmel.—Fish Hawk.

Rather rare; one or two seen about Lake Tahoe.

43. *Circus cyaneus* L., var. *hudsonius* L.—Marsh Hawk.

Present in the meadows through the mountains, and though not nearly so numerous as below, it is still common.

44. *Buteo borealis* (Gmel.), var. *calurus* Cass.—Western Red-tailed Hawk.

Abundant. With this hawk, as is the case with most of the species, a change of habitat is made necessary in the late fall, when snow and severe weather cause the disappearance of the small mammals, reptiles, and other game upon which it preys. They then move down into the valleys and remain about the lakes, where not only are found an abundance of water fowl, but where the marshes afford them an unfailing supply of certain small rodents through the season.

45. *Archibuteo lagopus* (Brunn.), var. *sancti-johannis*.—Rough-legged Buzzard.

Very numerous. In early November, in a meadow of considerable size not far from Lake Tahoe, I found that scores of this hawk had congregated. From one to half a dozen were visible at any hour of the day, sweeping with heavy wing over the surface of the turfy ground, and now and then dropping with almost certain aim upon one of the small Meadow Rats (*Arvicola riparius*) whose excavations honeycombed the ground in all directions, and whose immense numbers accounted for the unusual abundance of the hawks at this one locality.

46. *Aquila chrysaëtus* (L.)—Golden Eagle.

Apparently rather more numerous in this region than the succeeding bird.

47. *Haliætus leucocephalus* (L.)—Bald Eagle.

Rather rare. In fact eagles are rarely abundant in any portion of the west which I have visited, and the sight of one is an event of sufficiently unusual occurrence to attract the attention and elicit comment from the most unobservant of a party. The white-headed is much more numerous as an inhabitant of either coast than as a bird of the interior.

TETRAONIDÆ.

48. *Canace obscurus* (Say.)—Dusky Grouse.

The whole pine-timbered region lying along the eastern slope of the Sierras west of the Carson Valley, was formerly the home of very great numbers of this fine bird. Some of the stories told by the early settlers of its abundance are almost incredible.

The sound of the woodman's axe is followed by the almost complete abandonment of a locality, and chiefly from this cause and from the persecution they have been subjected to at the hands of the settlers and the Indians, the localities are very few where the grouse still exist in abundance. The steep sides of many of the deep cañons have proved inaccessible to the lumberman, and still retain the primeval growth of forest. Here the grouse still maintain their foot-hold, and will continue to do so long after the surrounding country has been swept bare of woods.

PERDICIDÆ.

49. *Oreortyx pictus* (Dougl.)—Plumed Partridge; Mountain Quail.

This beautiful bird ranges from the coast across the mountains, and is found along the eastern slope, where, at an elevation of about 6,000 feet, it is quite abundant. As noticed before, it reaches the lower foot-hills, but in very much diminished numbers. Usually a resident bird wherever found; the only effect winter has upon their range is to cause them to abandon the higher elevations occupied in summer, and to appear farther down upon the mountain-sides.

The mountains of this whole region lying about Lake Tahoe seem to be entirely abandoned by the species in winter, and a very complete migration takes place during the late fall. The flocks then pass not to the South, but westward, and winter upon the western slopes of the mountains, descending to a greater or less distance toward the foot-hills, according to the depth of snow, the severity of the weather, &c. Such at least is the explanation offered by the hunters and residents for their disappearance about November from this section, where earlier they are very abundant, and which I have every reason to believe is the true one. Those living in summer on the low foot-hills about Carson remain to winter. But those whose summer habitat is higher up in the mountains proper thus make a short migration to a region better adapted to their wants.

The snow upon the eastern slope falls to a great depth, and the winter is very severe, much more so than on the western side—facts which appear to have been thoroughly acquired by experience by these birds, till the habit of migration in anticipation of winter has become a fixed and constant one.

SCOLOPACIDÆ.

50. *Gallinago wilsonii* (Temm.)—Wilson's Snipe.

But a single one of this species was seen; this in a meadowy spot on the border of Tahoe in October.

ARDEIDÆ.

51. *Ardea herodias* L.—Great Blue Heron.

Common about Lake Tahoe.

52. *Botaurus minor* Gm.—Bittern.

Numerous on Lake Tahoe.

RALLIDÆ.

53. *Rallus virginianus* L.—Virginia Rail.

Saw but one, in a marsh near Lake Tahoe.

54. *Fulica americana* Gm.—Coot.

Extremely abundant in October and November about and on the lake.

ANATIDÆ.

55. *Anser hyperboreus* Pall.—Snow Goose.

Appears from the north in flocks in October, and sometimes make use of the lake as a temporary stopping-place.

56. *Branta canadensis* (L.)—Canada Goose.

Passes over the lake in great flocks, but less often rests here.

57. *Anas boschas* L.—Mallard.

Numerous in fall. This species appears to breed regularly in the little ponds and lakelets that abound in the mountains, and two or three flocks, each a little family group, will often be encountered in such places in fall ere they have started out in search of winter quarters.

58. *Mareca americana* Gm.—Baldpate.

Also occurring in fall.

59. *Querquedula carolinensis* (Gm.)—Green-winged Seal.

The only teal I saw about the lake. This species is rather numerous.

60. *Spatula clypeata* (L.)—Shoveller.

Probably breeds about the lake, but only in small numbers.

61. *Fuligula collaris* (Donovan.)—Ring-necked Duck.

In small numbers in fall; probably summers in the marshes of the lake.

62. *Oedemia* ———?

One of the large Sea Ducks occurs here in fall, and I saw several off the shores of the lake; the species I was unable to determine satisfactorily.

63. *Mergus serrator*, L.—Red-breasted Merganser.

A few seen on the lake in October.

PELECANIDÆ.

64. *Pelecanus trachyrynchus* Lath.—White Pelican.

Occasionally a flock strays on to the waters of the lake in fall.

GRACULIDÆ.

65. *Graculus dilophus* (Sw.)—Double-crested Cormorant.

A few of this species are said to pass the summer on the lake, where, however, they do not breed. They appear to leave the lake early in October, and I saw none at the time of my visit. Mr. Ridgway has identified the form from this region as the above

LARIDÆ.

66. *Larus delawarensis* Ord.—Ring-billed Gull.

I shot a single immature gull on Lake Tahoe, November 1, which I refer with but little doubt to this species. I am unable to state the numerical proportion which this bird bears to the next in this region during the late fall. According to Mr. Ridgway it should replace entirely in winter the next species.

67. *Larus californicus* Lawr.—Californian Gull.

Of five gulls shot on Tahoe, about November 1, four appear to belong to this species. They unquestionably winter here.

COLYMBIDÆ.

68. *Colymbus torquatus* Brunn.—Great Northern Diver.

I saw a number of specimens in possession of Mr. McKinney, which he had shot on the lake in fall. They do not appear to be very numerous.

69. *Podiceps auritus* (L.), var. *californicus* (Heerm.)—American Eared Grebe.

Very numerous all along the borders of Tahoe in fall. So utterly fearless and unsophisticated are they that they swim about the wharves, utterly regardless of the presence of humans but a dozen or twenty feet away.

APPENDIX J.

REPORT UPON THE HEMIPTERA COLLECTED DURING THE YEARS 1874 AND 1875, BY MR. P. R. UHLER.

PEABODY INSTITUTE, BALTIMORE, MD.,
March 24, 1877.

SIR: I have the honor to transmit the following report upon the Hemiptera collected by the expedition during the years 1874 and 1875.

Very respectfully, your obedient servant,

P. R. UHLER.

Lieut. GEO. M. WHEELER,
Corps of Engineers, in charge.

HETEROPTERA.

SUBFAMILY EURYGASTRINÆ.

Eurygaster, Lap.

E. alternatus.

Tetyra alternata, Say; Amer. Ent. iii. tab. 43, fig. 3.
Eurygaster alternatus, Dallas; Brit. Mus. List. Hemipt. i, p. 47, No. 1.

San Ildefonso, N. Mex., September, 1874, collected by Dr. H. C. Yarrow; also, near Colorado River, California, July 20, by William Somers.

SUBFAMILY ASOPINÆ.

Perillus, Stål.

1. *P. claudus.*

Pentatoma clauda, Say; Journ. Acad. Philad. iv, p. 312, No. 2.

San Ildefonso, N. Mex., in August, Dr. Yarrow and Mr. Shedd; also, Abiquiu, N. Mex., in September, and on the foot-hills and plains of that Territory in October, by Dr. O. Loew. Also, near the Mojave River, California, in July, Dr. O. Loew.

2. *P. splendidus.*

Zicrona splendida, Uhler; Proc. Ent. Soc. Philad. 1863, p. 22.

Found at Santa Barbara, Cal., in July, by Mr. Shoemaker, and in Southern California, by Mr. Henshaw.

ZICRONA, Am. et Serv.

Z. cuprea.

Zicrona cuprea, Dallas; Brit. Mus. List I, p. 108, No. 2.

Southern Colorado, in June, Lieut. W. L. Carpenter.

SUBFAMILY HALYDINA.

BROCHYMENA, Am. et. Serv.

B. obscura.

Halys obscura, H. Schf.; Wanz. Ins. v, p. 68, fig. 513.

From Pueblo, Colo., in July, Mr. Wilkins; also San Ildefonso, N. Mex., August 17, Dr. O. Loew.

PRIONOSOMA, Uhler.

P. podopioides.

Prionosoma podopioides, Uhler; Proc. Ent. Soc. Philad. 1863, vol. ii, p. 364.

From Santa Barbara, Cal. Collected by Dr. Loew.

SUBFAMILY PENTATOMINA.

EUSCHISTUS, Dallas.

1. *E. crenator.*

Cimex crenator, Fab; Ent. Syst. iv, p. 101, No. 87.
Pentatoma obscura, Palisot-Beauv; Ins. Afr. et Amer., p. 149, pl. 10, fig. 7.

Collected at Santa Barbara, Cal., in July, by H. W. Henshaw.

2. *E. impictiventris.*

Euschistus impictiventris, Stål; Enum. Hemipt. ii, p. 26, No. 21.

From San Ildefonso, N. Mex., in August, Mr. Shedd.

3. *E. fissilis.*

Euschistus fissilis, Uhler; In U. S. Geol. Surv. of Montana 1871, p. 396, No. 1.

Collected in Southern Colorado, June–July, by Lieut. W. L. Carpenter.

4. *E. servus.*

Pentatoma serva, Say; Heteropt. New Harmony, p. 4, No. 5.
Euschistus servus, Stål; Enum. Hemipt. ii, p. 26, No. 19.

From San Ildefonso. Collected by Dr. H. C. Yarrow.

Chlorochroa, Stål.

1. *C. ligata.*

Pentatoma ligata, Say; Heteropt. New Harmony, p. 5, No. 6.

From Camp Lowell, Ariz., September 9, by Mr. Johnson.

2. *C. Sayi.*

Chlorochroa Sayi, Stål; Enum. Hemipt. ii, p. 33, No. 6.
Pentatoma granulosa, Uhler; U. S. Geolog. Survey of Montana 1871, p. 398.

Collected at San Ildefonso, N. Mex., in July and August, by Dr. H. C. Yarrow; also in August, by Mr. Shedd; in Southern Arizona, by H. W. Henshaw; at Tierra Amarilla, N. Mex., September 15; at the San Juan River in New Mexico, by Mr. Browne, and on the plains and foot-hills of Northern New Mexico, in October.

THYANTA, Stål.

1. *T. rugulosa.*

Pentatoma rugulosa, Say; Heteropt. New Harmony, p. 7, No. 16.

From Southern Colorado, in October.

2. *T. perditor.*

Cimex perditor, Fab.; Ent. Syst., vol. iv, p. 102, No. 90.
Thyanta perditor, Stål; Hemipt. Fabr., vol. i, p. 29.

Obtained at Camp Bowie, Ariz., August 1, by Mr. Rutter; at Santa Fé, N. Mex., in June, by H. W. Henshaw; above timber-line in New Mexico, by Lieut. W. L. Carpenter; and in the Mojave desert, July, by G. Thompson.

Murgantia, Stål.

M. histrionica.

Strachia histrionica, Hahn; Wanz. Ins., vol. ii, p. 116, fig. 196.
Murgantia histrionica, Stål; Enum. Hemipt. ii, p. 37, No. 4.

Inhabits Plaza del Alcade, Arizona, in August, collected by Dr. H. C. Yarrow; Cave Spring, Arizona, July, H. W. Henshaw; Pueblo and San Ildefonso, N. Mex., Dr. H. C. Yarrow; New Mexico, in September, by S. Bedell, and Northern New Mexico, on the plains and foot-hills.

BANASA, Stål.

B. sordida.

Atomosira sordida, Uhler; Proc. Boston Soc. Nat. Hist. 1871, p. 6.

Originally obtained in Cambridge, Mass. The present specimen is from Tierra Amarilla, N. Mex., collected in July by Mr. Shedd. This is the first record of the occurrence of this insect in the region west of the Mississippi Valley.

ACANTHOSOMA, Curtis.

A. cruciata.

Edessa cruciata, Say; Heteropt. New Harmony, p. 8, No. 1.

Belongs to the regions north of the United States, but the specimens here reported were obtained at Abiquiu, N. Mex., by Dr. O. Loew.

FAMILY COREIDÆ.

SUBFAMILY COREINA.

MARGUS, Dallas.

M. inconspicuus.

Syromastes inconspicuus, H. Schf.; Wanz. Ins., vol. vi, p. 14, fig. 570.

Obtained at San Ildefonso, August 17, by Mr. Shedd, and by Dr. H. C. Yarrow; also in Southern Colorado, June 5, by Lieut. W. L. Carpenter.

CHELINIDEA, Uhler.

C. vittigera.

Chelinidea vittiger, Uhler; Proc. Ent. Soc. Phila., vol. ii, p. 366.

Collected in Northern New Mexico, June-July, by Lieut. W. L. Carpenter.

CATORHINTHA, Stål.

C. mendica.

Catorhintha mendica, Stål; Enum Hemipt., vol. 1, p. 187, No. 2.

Collected by Lieut. W. L. Carpenter, in Southern Colorado, June 5 to July 5.

ANASA, Amyot et Serv.

A. tristis.

Cimex tristis, De Geer; Mém. iii, p. 340. pl. 34, fig. 20.
Anasa tristis, Stål; Hemipt. Fabr. 1, p. 56, No. 3.

Collected at Colorado Springs, Colo., in July, and at San Ildefonso, N. Mex , in August, by Dr. H. C. Yarrow; Southern Colorado, June, L'eut. W. L. Carpenter.

SUBFAMILY ALYDINA.

STACHYOCNEMUS, Stål.

S. apicalis.

Alydus apicalis, Dallas; Brit. Mus. List II, p. 479.
Stachyocnemus apicalis, Stål; Enum. Hemipt. i, p. 215.

From the foot-hills and plains of New Mexico, in October, by Lieut. W. L. Carpenter.

SUBFAMILY MICTINA.

PACHYLIS, St. Farg.

P. gigas.

Pachylis gigas, Burm.; Handb. der Ent. ii, p. 338, No. 3.

Collected at the Bowie Agency, Ariz., August 15, by Mr. Johnson.

SUBFAMILY ANISOSCELIDINA.

LEPTOGLOSSUS, Guer.

1. *L. corculus.*

Anisoscelis corculus, Say; Heteropt. New Harmony, p. 12, No. 1.

From Tierra Amarilla, N. Mex., July, collected by Mr. Shedd; and from Arizona, by Mr. Rutter.

NARNIA, Stål.

N. femorata.

Narnia femorata, Stål; Stettin. Ent. Zeit. xxiii, p. 296, No. 154. Stål. Enum. Hemipt., vol i, p. 166, No. 1.

Collected at Camp Lowell, Ariz., August 23, by Mr. Henshaw.

SUBFAMILY BERYTINA.

NEIDES, Latr.

N. spinosus.

Berytus spinosus, Say; Amer. Ent., vol. i, pl. 14.

From Pueblo, Colo., collected by Dr. H. C. Yarrow.

SUBFAMILY PSEUDOPHLŒINA.

DASYCORIS.

D. humilis.

Dasycoris humilis, Uhler; U. S. Geological Survey of Montana, 1871, p. 403.

Obtained at Colorado Springs, Colo., in July, by Dr. Yarrow.

SUBFAMILY RHOPALINA.

CORIZUS, Fallen.

1. *C. Sidæ.*

Lygæus sidæ, Fab; Ent. Syst. iv, p. 169, No. 116.
Corizus sidæ, Signoret; Ann. Soc. Ent. France, ser. 3, vii, p. 95, No. 32.

Collected near the Mojave River, California, in July, Dr. O. Loew; also in the vicinity of the Colorado River, California, July 20, by W. Somers.

2. *C. hyalinus.*

Lygæus hyalinus, Fab; Ent. Syst. iv, p. 168, No. 115.
Corizus hyalinus, Stål; Hem. Fabr. i, p. 68, No. 2.

From Taos, N. Mex., in August, by Mr. Shedd; from Pueblo, Colo., in July, by Dr. Yarrow; and from Santa Fé, N. Mex., June, Mr. Henshaw.

LEPTOCORIS, Kahn.

L. trivittatus.

Lygæus trivittatus, Say; Journ. Acad. Philad. iv, p. 322, No. 2.
Leptocoris trivittatus, Stål; Enum. Hemipt. i, p. 226.

From Southern Colorado, July, Lieut. W. L. Carpenter.

FAMILY LYGAEIDÆ.

LYGAEUS, Fab.

1. *L. reclivatus.*

Lygæus reclivatus, Say; Journ. Acad. Philad. iv, p. 321, No. 1.

From Southern Arizona, Mr. Henshaw; San Ildefonso, N. Mex., Dr. Yarrow and Mr Shedd; Cave Spring, Ariz., July, Mr. Henshaw; Pueblo, Colo., July, Dr. Yarrow and Mr. Wilkin; Abiquiu, N. Mex., Dr. O. Loew; Mojave Desert, Cal., July, and near Mojave River, July, Dr. O. Loew.

2. *L. costalis.*

Lygæus costalis, H. Schf.; Wanz. Ins. vii, p. 22, fig. 706.

Obtained in California.

3. *L. fasciatus.*

Lygæus fasciatus, Dallas; Brit. Mus., Hemipt. ii, p. 538, No. 17.
Lygæus aulicus, H. Schf; Wanz. Ins. vi, p. 76, fig. 646.

Common in the Atlantic region south of Massachusetts; also in Texas, Mexico, and the West Indies. The only specimen in this lot was collected in Southern California, by J. A. Hasson.

MELANOCORYPHUS, Stål.

M. facetus.

Lygæus facetus, Say; Heteropt. New Harmony, p. 13, No. 2.

From the plains and foot-hills of New Mexico; June to October; collected by Lieut W. L. Carpenter.

MELANOPLEURUS, Stål.

M. bistriangularis.

Lygæus bistriangularis, Say; Heteropt. New Harmony, p. 14, No. 3.
Melanopleurus bistriangularis, Stål; Enum. Hemipt. iv, p. 169.

Collected at Camp Bowie, Arizona, August 8, by Mr. Albruiz.

NYSIUS, Dallas.

1. *N. angustatus.*

Nysius angustatus, Uhler; United States Geological Survey of Montana, 1871, p. 406, No. 2.

Obtained at Pueblo, Colo., in July, by Dr. Yarrow and Mr. Wilkin; at Fort Garland, in July, Mr. Hunt.

2. *N. californicus.*

Nysius californicus, Stål; Eugenies Resa, Hemipt., p. 242, No. 56.

Collected in New Mexico, in September, by S. Bedell; at Fort Garland, in August, by Mr. Shedd; July, by Dr. Yarrow, and in Southern California, June–July, by H. W Henshaw.

ISCHNORHYNCHUS, Fieb.

I. didymus.

Lygæus didymus, Zett; Vet. Akad. Handl. 1819, p. 71, No. 20.
Cymus Franciscanus, Stål; Eugenies Resa, p. 252, No. 84.
Ischnorhynchus didymus, Fieber; Europ. Hemipt., p. 199.

Southern Colorado, Dr. H. C. Yarrow.

GEOCORIS, Fallen.

1. *G. pallens.*

Geocoris pallens, Stål; Eugenies Resa, p. 250.

From the Mojave region, California, in July, Dr. Loew.

2. *G. bullatus.*

Salda bullata, Say; Heteropt. New Harmony, p. 18, No. 2.
Ophthalmicus borealis, Dallas; Brit. Mus. List, ii, p. 585, No. 8.

A specimen from Pueblo, Colo., collected by Dr. Yarrow; and a pale variety was obtained above timber-line in New Mexico, by Lieutenant Carpenter.

LIGYROCORIS, Stål.

L. constrictus.

Pamera constricta, Say; Heteropt. New Harmony, p. 15, No. 1.
Beosus abdominalis, Guer; La Sagra Hist. de Cuba, Ins., p. 397.

Southern Colorado, June and July, Lieut. W. L. Carpenter.

MYODOCHA, Latr.

M. serripes.

Myodochus serripes, Oliv; Encyc. Method., viii, p. 106.
Myodocha petiolata, Say; Heteropt. New Harmony, p. 19.

From New Mexico, August 23, by Dr. H. C. Yarrow.

TRAPEZONOTUS, Fieb.

T. nebulosus.

Lygæus nebulosus, Fallen; Mon. Cim., p. 65, No. 7.
Pamera fallax, Say; Heteropt. New Harmony, p. 17, No. 6.
Trapezonotus nebulosus, Fieber; Eur. Hemipt., p. 190.

From Southern Colorado, June–July, Lieut. W. L. Carpenter; also found above timber-line in New Mexico by the same gentleman.

PERITRECHUS, Fieb.

P. Fraternus.

Peritrechus fraternus, Uhler; Boston Soc. Nat. Hist. Proc., 1871, p. 11.

From Tierra Amarilla, N. Mex., in July, collected by Mr. Shedd.

SUBFAMILY LARGINA.

LARGUS, Hahn.

L. cinctus.

Largus cinctus, H. Schf.; Wanz. Ins., vol. vii, p. 6, fig. 683.

From Sienaga, Ariz., August 23, by Mr. Rutter; from Southern California, by Mr. J. A. Hasson; Santa Barbara, Dr. O. Loew; Southern Arizona, August, Mr. Henshaw; and from Camp Lowell, October 17, by Mr. Rutter.

FAMILY PHYTOCORIDÆ.

MIRIS, Auctor.

M. instabilis.

Miris instabilis, Uhler; Bulletin U. S. Geolog. Surv. of the Territories, vol. ii, No. 5, p. 50.

A very common insect in the Atlantic region and in Texas. The present specimen was collected above timber-line, in New Mexico, by Lieut. W. L. Carpenter, and also in Southern Colorado, in July.

PHYTOCORIS, Fallen.

P. nubilus.

Capsus nubilus, Say; Heteropt. New Harmony, p. 22, No. 10.

From near Colorado Creek, New Mexico, July 18, by Lieut. W. L. Carpenter.

LOPIDEA, Uhler.

L. media.

Capsus medius, Say; Heteropt. New Harmony, p. 22, No. 11.

Collected at San Ildefonso, N. Mex., in August, by Mr. W. C. Shedd; at Tierra Amarilla, N. Mex., in September, by Dr. H. C. Yarrow; in New Mexico, September, by S. Bedell.

LYGUS, Kahn.

1. *L. annexus.*

Lygus annexus, Uhler; U. S. Geological Survey of Montana, 1871, p. 413.

From Pueblo, in July, by Mr. Wilkin; Tierra Amarilla, N. Mex., September, Dr. H. C. Yarrow; Abiquiu, N. Mex., Dr. O. Loew; Northern New Mexico, Lieut. W. L. Carpenter

2. *L. lineatus.*

Lygœus lineatus Fab; Ent. Syst. Suppl., p. 541, No. 124-5. Syst. Rhyng., p. 234, No. 152, *Capsus 4-vittatus*, Say, Heteropt.; New Harmony, p. 20, No. 5.

An inhabitant of many parts of the United States from Northern New York to Texas. The present specimens were collected in Northern New Mexico, in June-July, by Lieut. W. L. Carpenter.

3. *L. lineolaris.*

Capsus lineolaris, Palisot-Beauv; Ins. Afr. et Amer., p. 187, pl. xi, fig. 7.

Common in most parts of temperate North America. From Northern New Mexico, June-July, Lieut. W. L. Carpenter.

4. *L. invitus.*

Capsus invitus, Say; Heteropt. New Harmony, p. 24, No. 21.

Sometimes common on the blossoms of *Vitis labrusca* in June, in Maryland.

A variety of this species was captured in Northern New Mexico, in June, by Lieut. W. L. Carpenter.

CALOCORIS, Fieb.

1. *C. rapidus.*

Capsus rapidus, Say; Heteropt. New Harmony, p. 20, No. 4.
Capsus multicolor, H. Schf; Wans. Ins. viii, p. 19, fig. 795.

Common in Eastern United States and in Texas. From Pueblo, Colorado, in June, by Dr. H. C. Yarrow; and from Tierra Amarilla, N. Mex., by S. Bedell.

2. *C. superbus.*

Calocoris superbus, Uhler; U. S. Geog. Survs. W. of 100th M., vol. v, 1875, p. 838, No. 2.

From San Ildefonso, N. Mex., August 17, by Mr. Shedd.

RESTHENIA, Amyot & Serv.

R. insignis.

Capsus insignis, Say; Heteropt. New Harmony, p. 22, No. 12.

Collected in Northern New Mexico, by Dr. H. C. Yarrow and Lieut. W. L. Carpenter.

CAMPTOBROCHIS, Fieb.

C. nebulosus.

Camptobrochis nebulosus, Uhler; U. S. Geolog. Survey of Montana, 1871, p. 417.

From Tierra Amarilla, N. Mex., by Dr. H. C. Yarrow.

STIPHROSOMA, Fieb.

S. stygica.

Capsus stygicus, Say; Heteropt. New Harmony, p. 24, No. 18.

From Northern New Mexico, July 18, by Lieut. W. L. Carpenter.

AGALLIASTES, Fieber.

A. associatus.

Agalliastes associatus, Uhler; U. S. Geolog. Survey of Montana, 1871, p. 419.

Collected at Pueblo, Colo., by Dr. H. C. Yarrow.

ORECTODERUS, Uhler.

1. *O. obliquus.*

Orectoderus obliquus, Uhler; Bulletin U. S. Geogr. Surv. of the Territories, vol. ii, No. 5, p. 54.

From Northern New Mexico, Dr. H. C. Yarrow.

2. *O. amœnus*, new sp.

Smaller and more slender than *O. obliquus*. Orange-fulvous, polished, not obviously punctured, the hemelytra dull, excepting the long cuneiform silvery white streak

opening from the base of the corium. Head much longer than wide, polished, narrowed behind the eyes, the width between the eyes scarcely narrower than the collum; face moderately decurving; eyes blackish, reniform, very prominent; antennæ moderately stout, rod-like, the basal joint constricted at its origin, the second joint very long, infuscated, of even thickness throughout; rostrum slender, infuscated, reaching upon the venter. Pronotum nearly bell-shaped, longer than wide, very narrow in front, finely polished, the posterior margin concave. Marginal lines of the corium all around, and of the clavus, brownish; cuneus infuscated at tip, and with a large white spot at base; membrane fuliginous, but paler at the basal angle. Legs long and slender, the tibiæ and tarsi tinged with piceous. Venter highly polished, orange, a little infuscated, moderately clavate posteriorly. Length to tip of venter 4½ millims. To tip of wing-covers 6 millims. Width of pronotum 1½ millims.

A single-wing cover is in the lot from New Mexico. Other specimens have been taken in Texas and Illinois.

FAMILY ACANTHIADÆ.

ACANTHIA, Fabr.

A. lectularia.

Cimex lectularius, Linn; Syst. Nat. ed. 12. vol. ii, p. 715, No. 1.
Acanthia lectularia, Fab; Ent. Syst. iv, p. 67, No. 1.
Acanthia lectularia, Amyot & Serv; Hemipt., p. 313, No. 1.
Acanthia lectularia, Fieber; Eur. Hemipt., p. 134, No. 1.

From Nothern New Mexico, October, Lieut. W. L. Carpenter.

FAMILY ARADIDÆ.

ARADUS, Fab.

A. rectus.

Aradus rectus, Say; Heteropt. New Harmony, p. 29, No. 4.

From the foot-hills of New Mexico, October, Lieut. W. L. Carpenter.

FAMILY PHYMATIDÆ.

PHYMATA, Lat.

P. erosa.

Cimex erosus, Linn; Syst. Nat. ed. 12, vol. ii, p. 718, No. 19.
Cimex scorpio, DeGeer; Mém. iii, p. 350, pl. 35, fig. 13.
Phymata erosa, Amyot & Serv; Hemipt., p. 290, No. 2.

From San Ildefonso, N. Mex., August 17, Mr. Shedd.

FAMILY NABIDÆ.

CORISCUS, Schrank.

C. ferus.

Cimex ferus, Linn; Fauna Suec., p. 256, No. 962.
Nabis ferus, Fiber; Eur. Hemipt., p. 161, No. 9.
Coriscus ferus, Stål; Enum Hemipt. iii, p. 113, No. 13.

Collected in New Mexico, and at Colorado Springs, Colo., June, by Dr. H. C. Yarrow; also Southern Colorado, June-July, Lieut. W. L. Carpenter, and above timber-line in New Mexico.

SUBFAMILY REDUVIINA.

PRIONOTUS, Lap.

P. cristatus.

Cimex cristatus, Linn; Cent. Ins. Rar., p. 16, No. 42. Amœn. Acad., vol. vi, p. 399, No. 42.
Reduvius novenarius, Say; Amer. Ent., vol. i, pl. 31, No. 2.
Arilus denticulatus, Westwood; Drury Illust., vol. ii, p. 73.
Prionotus cristatus, Uhler; Bulletin U. S. Geo. Surv. Territ., vol. ii, No. 5, p. 61.

A single specimen from Northern New Mexico, collected by Lieut. W. L. Carpenter.

PINDUS, Stål.

P. socius.

Pindus socius, Uhler; U. S. Geolog. Survey of Montana, 1871, p. 420.

From the plains and foot-hills of Northern New Mexico, in October, by Lieut. W. L. Carpenter.

SUBFAMILY APIOMERINA.

APIOMERINA, Hahn.

A. flaviventris.

Apiomerus flaviventris, H. Schf; Wanz. Ins., vol. VIII, p. 77, fig. 847.

A variety of this species was collected near Santa Fé, N. Mex., in June, by Mr. Henshaw; Northern New Mexico, June 5 to July 5, Lieut. W. L. Carpenter; also at Bowie, Ariz., August 8, by Mr. Albruiz.

SUBFAMILY PIRATINA.

RASAHUS, Stål. (Nec Amyot.)

R. liguttatus.

Petalochirus liguttatus, Say; Heteropt. New Harmony. p. 33, No. 2.
Pirates mutillarius, Guer; La Sayra, Ile de Cuba, p. 410. (Exclus. syn.)

From the Mojave Desert, California, by Dr. O. Loew, and from Los Angelos, in June by J. Brown.

MELANOLESTES, Stål.

1. *M. abdominalis.*

Pirates abdominalis, H. Schf., Wanz. Ins., vol. viii, p. 63, fig. 832.

Collected in Northern New Mexico, June–July, by Lieut. W. L. Carpenter.

2. *M. picipes.*

Pirates picipes, H. Schf; Wanz. Ins., vol. viii. p. 62. fig. 831.
Reduvius pungens, Lee; Proc. Philad. Acad. Nat. Sci. 1855, p. 404.
Melanolestes picipes, Stål; Enum. Hemipt., ii, p. 107, No. 3.

From Abiquiu, N. Mex., September, Dr. H. C. Yarrow.

SUBFAMILY ACANTHASPIDINA.

CONORHINUS, Lap.

C. rubrofasciatus.

Cimex rubrofasciatus, DeGeer; Mém. iii, p. 349, pl. 35, fig. 12.
Conorhinus rubrofasciatus, Amyot & Serv., Hemipt., p. 384, No. 1, pl. 8, fig. 2.

From Camp Lowell, Ariz., Mr. Rutter, August 23; and from near the Colorado River, California, July 20, by Mr. Somers; also from the Mojave Desert, by G. Thompson.

FAMILY STENOPODIDÆ.

STENOPODA, Lap.

S. culiciformis.

Cimex culiciformis, Fab; Ent. Syst., p. 728, No. 162.
Stenopoda cinerea, Lap, Essai, p. 26, pl. 52, fig. 2.
Stenopada culiciformis, Stål; Hemipt. Fabr., i, p. 129, No. 1.

A nympha of this species was collected at Abiquiu, N. Mex., by Dr. H. C. Yarrow.

FAMILY SALDIDÆ.

SALDA, Fab.

S. interstitialis.

Acanthia interstitialis, Say; Journ. Acad. Philada., vol. iv, p. 321, No. 1.

From Northern New Mexico, July, Lieut. W. L. Carpenter.

FAMILY HEBRIDÆ.

HEBRUS, Curtis.

H. sobrinus, new sp.

Robust, brunneo-fuscous, beneath chiefly black-piceous, with the sternum, coxæ, and legs testaceous. Head stout, not so long nor so tapering anteriorly as in *H. pusillus* Fallen, the vertex and face very convex, the tip thickly hairy; antennæ dull testaceous,

pubescent, the basal joint thickest, narrowed at base, longer than the second, the third longest, slender like the succeeding ones; under side of head and the bucculæ dull testaceous; the rostrum slender, reaching upon the venter, dull testaceous; eyes, dark brown, with coarse and few facets. Pronotum broader than long, flattened, the humeri well defined by a brown sulcus; impressed line between the lobes distinct, as also the three fovear on the centre, those of each side less distinct; the surface very minutely punctured; pleural pieces darker, with a few very remote, large punctures. Venter smooth, blackish-piceous, densely sericeous pubescent, margined with dull fulvous. Hemelytra pale brownish, minutely pubescent, the nervures darker, the membrane scarcely reaching to the tip of the abdomen.

Length scarcely 2 millimeters. Width of pronotum ⅞ millimeter.

Habitat.—New Mexico, Lieut. W. L. Carpenter. San Ildefonso, N. Mex., in July, Dr. H. C. Yarrow.

Family HYGROTRECHIDÆ.

Hygrotrechus, Stål.

H. remigis.

Gerris remigis, Say; Heteropt. New Harmony, p. 35, No. 1.

From water on the plains of Southern Colorado and Northern New Mexico, June, July, and October, by Lieut. W. L. Carpenter.

Family GALGULIDÆ.

Galgulus, Latr.

1. *G. oculatus.*

Naucoris oculata, Fab; Syst. Rhyng., p. 111, No. 5.
Galgulus oculatus, Latr; Hist. Nat. Ins., xii, p. 286, pl. 95, fig. 9.
Galgulus bufo, H. Schf; Wanz. Ins., v, p. 88, fig. 536.

Collected at San Ildefonso, N. Mex., August 17, by W. G. Shedd; Cave Spring, Ariz., Mr. Henshaw.

2. *G. variegatus.*

Galgulus variegatus, Guerin; Icon. Regne Animal, p. 352.
Galgulus pulcher, Stål; Öfv. Vetensk. Akad. Förhandl. 1854, p. 239, No. 1.

Santa Barbara, Cal., Mr. Henshaw and Dr. O. Loew; also at Abiquiu, N. Mex., Dr. H. C. Yarrow, in September.

Family NAUCORIDÆ.

Ambrysus.

A. Signoreti.

Ambrysus Signoreti, Stål; Hemipt. Mex. Stettin. Ent. Zeit., xxiii, p. 460, No. 336.
Naucoris Poeyi, Amyot & Serv; Hemipt., p. 434, pl. 8, fig. 5.

Taken at San Ildefonso, N. Mex., July, by Dr. H. C. Yarrow; in New Mexico, July, by Lieut. W. L. Carpenter; and in the Mojave River, Cal., in July, by Dr. O. Loew.

Family BELOSTOMIDÆ.

Belostoma, Auctor.

B. annulipes.

Belostoma annulipes, H. Schf; Wanz. Ins., viii, p. 28, figs. 803, 804.

A nympha was taken near San Ildefonso, in July, and an imago at Pagosa, Colo., September 5, by Dr. H. C. Yarrow.

Pedinocoris, Mayr.

1. *P. macronyx.*

Pedinocoris macronyx, Mayr; Verhandl. Wien. Zool.-Botan. Gesell, 1863, p. 350, tab. 11, figs. 1-4

Obtained in the Gila River, Arizona, by Dr. C. G. Newberry.

2. *P. indentata.*

Zaitha indentata, Hald., Proc. Acad. Philada., vi, p. 364.
Pedinocoris brachonyx, Mayr; Verhandl. Wien. Zool.-Botan. Gesell, 1863, p. 351, tab. 11, fig. 5.

From the Mojave River, California, July, Dr. O. Loew, and from Kernville, Cal., by Mr. Henshaw, September 2.

ABEDUS, Stål.

A. breviceps.

Abedus breviceps, Stål; Stettiner Ent. Zeit., xxiii, p. 462.

Collected at San Ildefonso, N. Mex., August 17, by Mr. Shedd; Camp Lowell, Arizona, August, Mr. Henshaw, and in Arizona, July, by Mr. Rutter.

FAMILY NOTONECTIDÆ.

NOTONECTA, Linn.

1. *N. undulata.*

Notonecta undulata, Say; Heteropt. New Harmony, p. 39, No. 1.

From Abiquiu, N. Mex., September, by Dr. Yarrow, and San Ildefonso, N. Mex., August 17, Mr. Shedd.

2. *N. insulata.*

Notonecta insulata, Kirby; Fauna Bor. Amer., iv, p. 285, No. 399.
Notonecta rugosa, Fieber; Rhynchotographien, p. 52, No. 7.

Collected at Camp Lowell, Ariz., in August, by Mr. Henshaw, and elsewhere in Arizona, in July, by Mr. Rutter.

FAMILY CORISIDAE.

CORISA, Geoff.

1. *C. interrupta.*

Corixa interrupta, Say; Journ. Acad. Philada., iv, p. 328, No. 1.

From New Mexico, in October, by Lieut. W. L. Carpenter, and from San Ildefonso, N. Mex., by Dr. H. C. Yarrow.

2. *C. alternata.*

Corixa alternata, Say; Journ. Acad. Philada., iv, p. 329, No. 2.

From San Juan River in New Mexico, by Mr. Browne.

3. *C. sutilis.*

Corixa sutilis, Uhler; Bulletin U. S. Geogr. Surv. of the Territ., vol. ii, No. 5, p. 73.

From the plains of Northern New Mexico, in October, by Lieut. W. L. Carpenter.

HOMOPTERA.

FAMILY STRIDULANTIA.

CICADA, Fab.

1. *C. synodica.*

Cicada synodica, Say; Journ. Acad. Philada., vol. iv, p. 334, No. 6.

From Southern Colorado, June–July, by Lieut. W. L. Carpenter.

2. *C. rimosa.*

Cicada rimosa, Say; Journ. Acad. Philada., vol. vi, p. 235, No. 2.

Collected in Southern Colorado, June–July, by Lieut. W. L. Carpenter.

FAMILY MEMBRACIDÆ.

CERESA, Fairm.

C. bubalus.

Membracis bubalus, Fab., Ent. Syst., vol. iv, p. 14, No. 23.
Ceresa bubalus, Fitch; Catalogue of Ins. N. Y. State Cabinet, p. 50, No. 632.

From San Ildefonso, N. Mex., and near Pueblo, Colo., by Dr. H. C. Yarrow; also from San Ildefonso, by Mr. Shedd.

SMILIA, Germar.

S. vau.

Membracis vau, Say; Journ. Acad. Philada., vol. vi, p. 299, No. —.
Smilia vau, Fitch; Cat. of Ins. of N. Y. State Cabinet, p. 48, No. 658.

Collected in Northern New Mexico, June-July, and also in October, by Lieut. W. L. Carpenter.

CAMPYLENCHIA, Stål.

C. curvata.

Membracis curvata, Fab., Syst. Rhyng., p. 13, No. 34.
Membracis latipes, Say; Long's Exped., ii, p. 302, No. 5.
Enchenopa Antonina, Walk; Brit. Mus. List. Homopt. ii, pp. 488-491, Nos. 32, 33, 35, 36, 37.
E venosa, Walk; Brit. Mus. List. Homopt. ii, pp. 488-491, Nos. 32, 33, 35, 36, 37.
E. densa, Walk; Brit. Mus List. Homopt. ii, pp. 488-491, Nos. 32, 33, 35, 36, 37.
E frigida, Walk; Brit. Mus. List. Homopt. ii, pp. 488-491, Nos. 32, 33, 35, 36, 37.
E. bimaculata, Walk; Brit. Mus. List. Homopt. ii, pp. 488-491, Nos. 32, 33, 35, 36, 37.

Collected in New Mexico, by Mr. Rutter.

PUBLILIA, Stål.

P. modesta.

Publilia modesta, Uhler; Bulletin U. S. Geolog. Survey of the Territ., vol. ii, No. 5, p. 78, No. 2.

Collected at San Ildefonso, N. Mex., by Dr. H. C. Yarrow, and at Cave Spring, Ariz., by Mr. Henshaw.

DARIUS, Fab.

An immature specimen of species allied to *D. lateralis*, Fab., was in the collection of Dr. O. Loew, from the Mojave Desert, California.

TELAMONA, Fitch.

T. pyramidata, new sp.

Similar in form to *T. querci*, Fh., but not quite so broad, the base of the dorsal prominence more compressed. Color (of the alcoholic specimen) yellowish, clouded with brown, particularly on the sides and tip of the prominence; also at the end of the scutellum, and on the base and more largely on the tip of the hemelytra. Head uneven, yellowish, remotely, finely and irregularly punctured with brown; cheeks and rostrum hairy. Pronotum with brown, coarse, sunken punctures, the punctures finer anteriorly and placed less closely, and so, also, a little way from the apex; central carinate line interruptedly brown, smooth; humeri prominent, laminar, almost rectangular. Dorsal prominence subpyramidal, compressed above, the tip rounded, edged with piceous, with a few coarse, deep, dragged punctures, which are bounded by tumid, almost linear, oblique interstices; the carinate line continued to the tip of pronotum, and paler both below and behind the summit; the apex, with four irregular, longitudinal rows of punctures, with raised linear interstices; lateral edge smooth pale, somewhat interrupted with brown. Hemelytra obscured hyaline, with a large oval spot at tip; their extreme base, the two upper nervures on the middle, and the punctures bounding the nervures each side throughout their length brown. Legs yellowish, tinged with piceous, the tibiæ spotted with brown on their outer sides; bristles pale yellowish, the base and extreme tip of tarsi, and the nails piceous. Venter blackish, with the incisures yellowish.

The hemelytra extend considerably beyond the pronotum and are obliquely narrowed at tip.

Length to tip of pronotum, 8 millimeters; to tip of hemelytra, 9 millimeters. Width between the humeral angles, 4 millimeters. Altitude to summit of dorsal prominence, scant 4 millimeters.

Collected in Southern Colorado, in July, by Lieut. W. L. Carpenter.

FAMILY FULGORIDÆ.

SCOLOPS, Germar.

S. sulcipes.

Fulgora sulcipes, Say; Journ. Philada. Acad., vol. iv., p. 335.

Obtained in Southern Colorado, June-July, by Lieut. W. L. Carpenter.

FAMILY TETTIGONIDÆ.

PROCONIA, Amyot & Serv.

P. costalis.

Tettigonia costalis, Fab., Ent. Syst., Suppl., p. 516, Nos. 22, 23. Signoret, Ann. Soc. Ent. France, 3d ser., ii, p. 359, pl. 12, fig. 8.
Cercopis marginella, Fab., Syst. Rhyng., p. 96, No. 44.
Cercopis lateralis, Fab., Ent. Syst., Suppl., p. 524, No. 24. Coquebert, Illustr., vol. i, p. 35, tab. 9, fig. 3.
Tettigonia lugens, Walker; Brit. Mus. List, Homopt., iii, p. 775, No. 108.
Tettigonia pyrrhotelus, Walk., l. c. iii, p. 775, No. 109.

Widely distributed in North America, occuring on both sides of the continent, and as frequent in the cold north of British America as in the warm regions of the subtropics.

Captured near Abiquiu, N. Mex., by Dr. O. Loew.

TETTIGONIA, Sign. (Geoff.)

T. hieroglyphica.

Tettigonia hieroglyphica, Say; Jour. Acad. Philada., vol. vi., p. 313, No. 6.

Taken in Northern New Mexico, by Lieut. W. L. Carpenter, and in the Mojave Desert, in July, by Dr. O. Loew.

HELOCHARA, Fitch.

H. communis.

Helochara communis, Fitch; Heteropt., New York State Cabinet, p. 56., Nos. 753, 754.

Taken in Northern New Mexico, in July, by Lieut. W. L. Carpenter.

BYTHOSCOPUS.

B. siccifolius.

Bythoscopus siccifolius, Uhler; Bulletin U. S. Geolog. Survey of the Territories, vol. ii, p. 93, No. 2.

Taken in New Mexico, September, by Lieut. W. L. Carpenter.

Many specimens of APHIDÆ, obtained from various kinds of plants, are included in several of the bottles, but they are changed too much by their alcoholic bath to admit of correct determination.

APPENDIX O O.

ANNUAL REPORT OF CAPTAIN G. J. LYDECKER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

EXPLORATIONS AND SURVEYS, MILITARY DIVISION OF THE MISSOURI.

HEADQUARTERS MILITARY DIVISION OF THE MISSOURI,
OFFICE OF THE CHIEF ENGINEER,
Chicago, Ill., September 25, 1877.

GENERAL: I have the honor to submit the following report of operations connected with this office for the fiscal year ending June 30, 1877:

By General Order No. 6, Headquarters Military Division of the Missouri, I was "announced as chief engineer officer on the division staff, during the temporary absence of Maj. George L. Gillespie, Corps of Engineers," in pursuance of Special Orders No. 85, current series, from the Headquarters of the Army.

Since assuming charge, I have had no funds for defraying expenses incident to operations pertaining to the duties of this office, consequently it has been impossible to accomplish any work worthy of note. The record shows that about the same condition of affairs existed during Major Gillespie's administration, viz: from July 1, 1876, to May 1, 1877, telegraphic instructions from the Chief of Engineers, dated July 29, 1876, having directed as follows: "Appropriations for surveys, &c., having failed in Congress, no indebtedness will be incurred subsequent to July 31, 1876."

All work done in the office has been by a man detailed from those enlisted for the general service, and has consisted generally in the routine business, such as making duplicate tracings of sketches, maps, &c., accompanying reports passing through this office, and which are required to perfect the files in the office of the Adjutant-General; these frequently furnish data for correcting inaccuracies in existing maps, and whenever found the corrections have been made. It has not been practicable, however, to make any progress on the new maps of the Western Territories. This work should be resumed with as little delay as practicable, for the information which the maps will contain is greatly needed in carrying on the operations against the Indians, and for various other public purposes.

For the above object, and in order that any practical benefit may be derived from the continuation of this office, it is necessary that an appropriation sufficient for the work should be made available.

The amounts required for this purpose are as follows:

For part of the fiscal year ending June 30, 1878	$3,000 00
For the fiscal year ending June 30, 1879	6,000 00

With less than the above but little good can be accomplished.

Very respectfully, your obedient servant,

G. J. LYDECKER,
Captain of Engineers, U. S. A.,
Chief Engineer Military Division of the Missouri.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

APPENDIX PP.

ANNUAL REPORT OF LIEUTENANT EDWARD MAGUIRE, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF DAKOTA.

HEADQUARTERS DEPARTMENT OF DAKOTA,
CHIEF ENGINEER'S OFFICE,
Saint Paul, Minn., June 30, 1877.

GENERAL: I have the honor to submit herewith my annual report for the fiscal year ending June 30, 1877.

At the close of the fiscal year, the engineer detail in this department consisted of myself as engineer officer and a detachment of the battalion of engineers, consisting of two sergeants and four privates. One private was discharged July 14, 1876, in consequence of the expiration of his term of service, but with this one exception the detachment served with the troops in the field till September 7, 1876, when the campaign having virtually terminated, it returned to Saint Paul. One sergeant was, January 8, 1877, transferred to the Department of the Platte at the request of the engineer officer of the Division of the Missouri. While in the field the attention of the detachment was devoted to topographical work and the collection of such information as was possible. In addition to the topographical work, I was engaged in the superintendence of the bridging and crossings of streams and in such road-making as was found to be necessary in order to allow the passage of the train. A full report of last summer's work was submitted to the Brigadier General commanding this department, and a copy of it was forwarded to the Chief of Engineers.

Since the return to this city the office work has consisted in the arrangement, compilation, and plotting of the notes taken last summer, in the performance of such duties as were found necessary in the routine operations of the department, and in collecting such information relating to this department as could be obtained. There have been numerous calls for maps, tracings, and information of a varied nature, not only from military sources but from citizens interested in the country west of the Missouri River, from the superintendent of Indian affairs in this district, and from steamboat-men.

In addition to the above-mentioned work I have furnished working-drawings and specifications for and superintended the construction of trestle-bridge material to be used during the coming campaign.

An appropriation of $2,500 having been made for the improvement of the road from Springfield, Dak., to White Swan, Dak., I received orders to examine and report upon the said route. This duty was performed.

Upon the recommendation of the Quartermaster-General the sum of $10,000 was set aside from the appropriation for transportation of the Army to be expended in the improvement of the Yellowstone River. As the engineer officer of this department I was placed in charge of the

work, but with instructions to confine the work to the three points known as Wolf, Baker, and Buffalo Rapids. As the appropriation expired with the fiscal year it became necessary for me to make a contract with each employé by which he agreed, for and in consideration of a certain sum, to remove the obstructions to navigation in the Yellowstone by the 1st of November; and should the work be finished before that time, there should be deducted from that sum an amount equivalent to pay for the number of days between the date of cessation of work and the 1st of November, at the rate of so much per day.

There is still much topographical work to be done in this department, but it is impossible at present to furnish an estimate of the amount which can be accomplished during the next fiscal year. The approaching campaign and the construction of the two large posts on the Yellowstone and Big Horn absorb all the attention and troops in this department. It is to be hoped, as expressed in a letter from this office to the Chief of Engineers, dated the 11th instant, "that the Indian problem will receive such a solution this summer that it will be possible next spring to fill in some of the gaps now existing on the maps."

Upon my application to the department commander two officers (Lieut. L. R. Hare, Seventh Cavalry, and Lieut. O. F. Long, Fifth Infantry,) have been detailed as acting engineer officers to accompany the troops serving in the field. Their notes will be plotted when received, and it is hoped that new information will be gained.

Orders have been issued for the survey of Tongue River reservation, and the survey will be made, other duties permitting.

The entire office work for the year has been well performed by the different enlisted men of the detachment.

Very respectfully, your obedient servant,

EDW. MAGUIRE,
First Lieutenant of Engineers.

The CHIEF OF ENGINEERS
United States Army.

EXPEDITION AGAINST THE HOSTILE SIOUX INDIANS IN THE SUMMER OF 1876.

HEADQUARTERS DEPARTMENT OF DAKOTA,
CHIEF ENGINEER'S OFFICE,
Saint Paul, Minn., March 9, 1877.

GENERAL: I have the honor to forward by to-day's mail a copy of the report submitted by me to the Brigadier General commanding this Department.

As will be seen from the report and the map, the line of march* was generally over portions of the country which had been traversed before and upon the nature of which other reports had been submitted. I have expressed my views concerning that region simply because men differ in their ideas of the quality of things, and any opinion which, though when considered by itself may be of little importance, yet when compared with or added to others, aids in forming true estimates.

There is still much work to be done in this department in the way of reconnaissances, but the unsettled condition of Indian affairs, with the consequent drain upon the different posts for troops to serve in active operations against the hostiles, will preclude all idea of obtaining an

* Map on file in Engineer Department, Washington, D. C.

escort large enough to furnish adequate protection during the coming season.

Colonel Miles, Fifth Infantry, with a command of about 2,400 men, will commence operations this year, but my experience last summer taught me that very little work could be done on a military expedition, and as the two new reservations, one at Tongue River, 20 miles square, and the other at the mouth of the Little Big Horn or Custer River, must be surveyed, I have concluded to start up the Yellowstone about May 1, for the purpose of laying out these reservations.

Very respectfully, your obedient servant,

EDW. MAGUIRE,
First Lieutenant Corps of Engineers,
Chief Engineer Department of Dakota.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

REPORT.

HEADQUARTERS DEPARTMENT OF DAKOTA,
CHIEF ENGINEER'S OFFICE.

SIR: I have the honor to submit the following report:

In obedience to Special Orders No. 80, War Department, Adjutant-General's Office, April 21, 1876, I reported for duty at these headquarters May 8, 1876, relieving Capt. William Ludlow, Corps of Engineers, of his duties as chief engineer of this department; and in compliance with Special Orders No. 64, Headquarters Department of Dakota, dated May 9, 1876, I proceeded to Fort Abraham Lincoln, May 10, to join the expedition against the hostile Sioux.

After a delay of a few days, due to rain, the column finally started from the encampment at 5 a. m., May 17, and commenced its march into the land of the turbulent Dakotas.

The morning was raw and cold, and a heavy mist hung over the whole region round about. It gradually rose, however, as we passed Fort Lincoln, and when we reached the foot of the long ascent leading to the prairie above, it was a very beautiful sight, that of the gradual fading-out of the mist-bows and the rolling upward of the mist.

The column took up the line of march almost due west for Heart River. The route was over a rolling prairie, which was found to be in fair condition for the wagon-train. This was surprising, as after the heavy rain it was expected that the ground would be very soft; but the train experienced no difficulty, and at half past one in the afternoon, after a march of 13½ miles, we encamped on Heart River. The camp was established in the bottom, which is about 500 feet square, and was fenced in on three sides by high bluffs, the fourth side being bounded by the gentle slope leading to the prairie we had just traversed. Quite a number of rattlesnakes, from 2 to 2½ feet long, were killed in the camp. The grass was good and plentiful, and there was no lack of wood. A slight rain fell during the night. The water of the Heart was the first we had seen after leaving Fort Lincoln. The river is so named from a prominent butte which is supposed to present the appearance of a gigantic heart.

The Indian scouts furnished much amusement. They were all, with one exception, members of the tribe called Arickarees. This one exception was Bloody Knife, a half Sioux, the hero of many fights.

The Arickarees were formerly a large and war-like tribe, living on Grand River, but small-pox and other diseases have brought them to their present state. They are of medium size and quite dark. Judging from the council held with them by Col. G. A. Custer they are not without a sort of rude eloquence. They had at all times a dirty appearance, and when mounted they looked not unlike antiquated negro washerwomen. They appeared to be a sedate class of men, even the younger ones scarcely ever smiling. They paid but little attention to their personal appearance, and I saw but few and slight attempts at ornamentation of any kind. They acknowledge the existence of one Supreme Being. They also worship the "Mother," who has especial charge of them, and who, on leaving them ages ago, left them an ear of corn as a legacy. Their legends state that this Mother led them into the heart of a mountain and drove in for them various kinds of game. After a time one of the tribe, while exploring, crawled out into this country. On his report they enlarged somewhat the hole, and a portion of the race came forth into this land; but finally, a woman who was enormously big with child could not pass through, and the hole is closed to this day, a portion of the race remaining in the mountain. They have no established form of worship. They make use of offerings, and these offerings placed on the top of a pole in the prairie are held sacred by all, even hostile tribes, and never disturbed.

There is some chastity among them, but it is not general. Courtship and marriage among them are simply a bargain, the lover giving the father the number of ponies he demands. This number varies with the social and political standing of the father. There is no marriage ceremony. In taking a wife the husband is entitled to his sisters-in-law who live with and work for him, and are disposed of in marriage by him. There is seldom any disagreement among the wives, and each treats the others' children as her own.

Their divorce-law is as a law without essence; that is to say, a man may put away his wife at will and she returns to her parents or relatives.

Their language contains about seven hundred and fifty words. Their composition is crude, their most definite rule of grammatical construction being that for distinguishing the genders. Masculine is changed into feminine by prefixing an *S*.

They can count up to one thousand, but beyond that they must resort to sticks. Their term for twenty signifies a man, from the fact that a man has ten fingers and ten toes.

Their rulers or chiefs are elected, and are generally chosen with a view to generosity, courage, and intellect.

They have numerous legends and songs. The latter, as with all primitive people, are usually of battle or the chase.

They have the reputation of being very brave, and, indeed, well-known officers of the Army are willing to testify to their character in this respect. Yet, the whole time they were with us they could not be induced to go any distance in advance of the troops. Before the column left Fort Lincoln they said that we would meet a great many Indians, and, acknowledging their claims to being considered a brave tribe, the only theory, and it is thought the true one, to account for their apparent cowardice, was the fact that they knew that there were more hostiles in the field than were supposed to be, and yet had no precise knowledge of where these hostiles would be encountered.

Their appetites are gross. They eat the intestines of animals either

cooked or raw, and their favorite morsels are a fœtus of an antelope, elk, or deer, and the raw liver taken warm from the freshly-killed animal.

The next morning (18th) the command moved again, crossing Heart River. The Heart at this point is about 30 yards wide, 3 feet deep, with a fairly firm sandy bed and a slight current. The water was clear and good. A great deal of work was required in corduroying the bank to enable the train to cross, and it was only after a delay of three hours that the head of the column commenced its march for the Sweetbriar, on a branch of which we encamped at 1.45 p. m., after a journey of 10¾ miles. Camp was established on a plateau of about 70 acres, 50 feet above the creek. This branch of the Sweetbriar is about 10 feet wide and 4 feet deep, with a soft, muddy bed. It contains quite a number of small fish. The quantity of wood was small, and the grass fair. We were greeted on our arrival with a severe rain-storm which lasted about twenty minutes. The rain continued to fall at intervals of half an hour or so during the remainder of the day. The country between the Heart and this camp is covered with a well-defined drift containing numbers of bowlders, (often found to be arranged in almost perfect circles on the summits of the hillocks,) quartzose, feldspathic and siliceous limestones. On this march we caught our first glimpse of the "bad lands." They were of small extent.

The next day's march of 13½ miles brought us to Crow's Nest, or Buzzard's Roost Butte. The first portion of the route lay over an exceedingly rough country covered with drift. After struggling over a distance of 1¼ miles we arrived on the banks of the Sweetbriar. It was found to be a rushing torrent fully 50 feet wide, and much over 10 feet in depth. To cross it with the means at hand was impossible, so it was determined to go southward and turn the stream. This was done, and skirting the valley we passed out into an open, flat, and marshy prairie, in a northwesterly direction towards "Crow's Nest." The ground was very soft and interspersed with fragments of slate, and the last 4½ miles were passed over a swamp, double teams being necessary for each wagon. At noon a terrible storm arose. The rain came down as in sheets, while for twenty minutes hail five-eighths of an inch in diameter descended with great violence. Fortunately none of the herd were stampeded, but darkness fell upon us before the last wagon was parked. "Crow's Nest" consists of two peaks, the eastern one being considerably taller than the other. It is so called from the fact that large numbers of crows formerly built their nests and brooded there. Twin Buttes are plainly visible from the eastern peak bearing 254½° and 255½°. The only water at this camp was that in coulées and "buffalo-wallows." There was no wood easily accessible, and the grass was poor. A large portion of the command were unable to cook supper or breakfast. The bridge was laid once during this march.

At 5 the next morning I left camp with Reynolds, the guide, and ten Indian scouts, to look for a crossing of the Big Muddy Creek. Numbers of antelope were seen. A crossing was found, but returning we met the command, which had moved at 7.30 a. m., and it was decided to turn the stream. During the journey a branch of Muddy Creek was crossed by a bridge. After a march of 9½ miles the command encamped on another branch of the Big Muddy Creek at 1.30 p. m. The grass along the route was thin and the ground soft, but the train encountered but few and slight difficulties. A heavy rain fell during the night.

The following day the creek was crossed by a bridge. The stream is about 9 feet in width and 1½ feet deep. The day opened foggy and rainy. The first portion of the route was nearly northwest toward Big-

Butte, then turning west the march was along the eastern edge of a line of bluffs overlooking an extensive area of bad lands, in the center of which are situated "Twin Buttes," or "Maiden's Breasts," so called from their appearance. Camp was established on another branch of the Big Muddy, crossed by bridge at 3.30 p. m., after a march of 13½ miles.

"Cherry Ridge," a long, prominent, and well-timbered range of hills, was visible all day. In addition, numerous buttes were in view during the march, among which were "Wolf's Den" and "Big Butte."

The grass was fair, but the soil was often rocky. There was no timber nearer than 2 miles from camp, and that was but a pocket of small growth.

Breaking camp the next morning, the route lay nearly southwest over a low swamp, which proved to be the headwaters of the Big Muddy. Crossing this swamp, we ascended the divide on the south side of the Big Muddy Valley, the course then turning westward over a firm and finely-grassed country intersected by well-wooded ravines. From this divide the timbered valley of the Muddy could be seen to the south. Reaching the headwaters of a branch of Knife River, we proceeded along the left bank for about 6 miles, and then turning southwest of the valley the road led up a steep hill covered with sage and cactus, there being little or no other vegetation. Large alkaline patches were prominent features of the country. Moving around the summit of the hill, we again descended to the valley of the stream, ("Thin-faced Woman's Creek,") and crossed the latter by bridge. The creek is well wooded; the banks are steep, and it is about 20 feet wide and 12 feet in depth. There was no water at the crossing, but a sufficient quantity was obtained from pools a short distance from camp. A few elk were seen during the march.

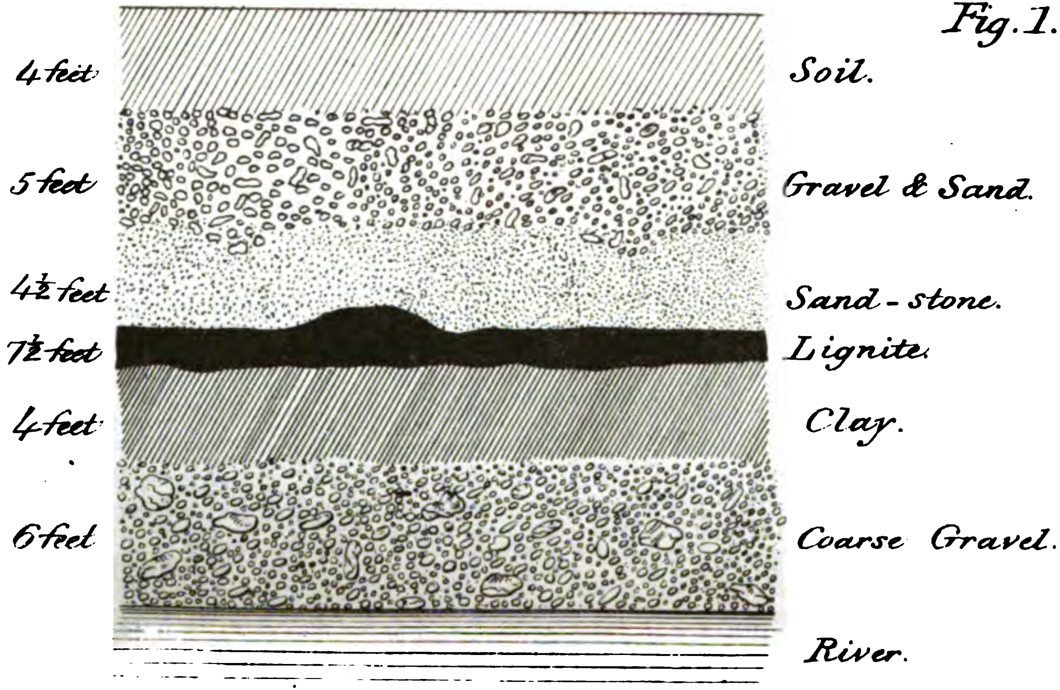
Starting at 5.30 the next morning, and passing Young Men's Butte about 8.20, we encamped at 8.40 a. m. near the springs which form the headwaters of another branch of Knife River. There was plenty of good water, wood, and grass. The valley of Knife River is visible for 30 miles from this point. It is well timbered and of considerable width. Elk, black-tail deer, and antelope were seen during the day.

Leaving the camp near Young Men's Butte, we crossed the divide between Knife River and a branch of Heart River, and encamped on the latter a short distance from the river itself. The main stream receives the branch about 1½ miles from this camp. The branch is about 30 feet wide and 1 foot in depth, with a hard, gravelly bed. The current is swift, and the water is clear but alkaline, and contains quite a number of small fish. The grass around camp was good, and, like the wood, plentiful. A great many elk and one lynx were seen in this region. During this march we encountered for the first time limited fields of a species of primrose. The flowers were very beautiful, and as they were crushed under the horses feet they gave forth a protest of the most delicate and welcome odor.

On the morning of May 25 we forded the branch of the Heart, and, crossing the divide, encamped on what is called North Fork of Heart River. The grass in and around camp was good; there was plenty of wood and fair water. The bridge was laid twice during the march.

Having crossed the North Fork by bridge, we ascended a long and easy slope to an alkaline plain covered with cactus and prickly pears. After a march of about 5 miles, the North Fork was crossed again by bridge. The stream at this point is well timbered, and its course can be seen for fully 12 miles. After crossing several tributaries, the command finally encamped on one of the latter about 2 o'clock in the after-

Fig. 1.


4 feet
Soil.
5 feet
Gravel & Sand.
4½ feet
Sand-stone.
7½ feet
Lignite.
4 feet
Clay.
6 feet
Coarse Gravel.
River.

noon. The grass was excellent, but there was no wood. The weather was very warm, and the mosquitoes troublesome. Millions of young grasshoppers were seen covering the ground. The bridge was laid three times during the day. We were visited by a heavy rain-storm at night.

The next morning opened up quite foggy, but, breaking camp at the usual hour, the command proceeded in a south-southwest direction for nearly 7 miles, when we came in full view of the bad lands of the Little Missouri. These bad lands, as seen from a distance, present a very striking and picturesque appearance, forcibly reminding one of the ruins of some great city destroyed by fire. This effect is heightened by occasional patches of brilliant red clay, which glisten in the sunlight like beacon-fires. Upon a near approach the beauty of the scene vanishes into thin air. One finds but deep and tortuous ravines flanked by almost perpendicular bluffs of alkaline clay. In addition to the bluffs, there are numerous solitary formations, usually conical in shape, and some of these have layers or bands very distinctly marked, as with a brush. The surface of the conical formations is quite hard, but detached pieces of the clay offer but slight resistance to being crushed to an impalpable powder. Different varieties of clay, argillaceous limestones, and friable sandstones are encountered. Beds of lignite appear at almost every step, and occasionally a burning bed is to be seen. The clays are of divers shades, running through black, brown, red, yellow, blue, and gray to pure white. Often the ground and hill-sides are strewn with slag-like masses, which bear strong evidences of having been fused. Some of them have a vitreous luster, others looking very much like bog iron-ore.

The lignite is of an impure variety, sometimes of a dead black color, with a conchoidal fracture, and resembling cannel-coal; at other times it is brown, with a decided vegetable structure. In the descent to the valley of Powder River, where a road had been cut in the side hill, there was found a bed of lignite. Specimens taken from it broke freely in laminæ, and the fracture showed numerous projections like black shells of a small size imbedded in the lignite. These raised shell-like portions were black, and of a bright vitreous luster, while the matrix, if it may be so termed, was of a dull black color, with a slightly brownish tinge. The lignite does not burn well. It is difficult of ignition, and a white ash is produced by combustion.

The valleys of the streams appear to be all of the same nature, varying simply in extent. The following section of the banks of the Yellowstone, near the mouth of Powder River, furnishes a type of the general formation of the whole section. (See Fig. 1.)

The drift consists of various kinds of siliceous pebbles and stones, often containing beautiful specimens of moss and fortification agates. Silicified wood is common. The clay is of different shades of yellow, blue, and gray, some being of dazzling white. The sandstone is usually of a light-yellowish color, but is quite often found in dislodged masses on the bluffs of a dark rusty or brown color. It is quite soft and can be broken readily by hand. With the exception of drift, and now and then small quantities of shale or indurated clay, this sandstone was the only kind seen during the whole season.

From the point where we first caught sight of the bad lands the course was turned nearly due south, and having marched a distance of about 5 miles, a halt was ordered to determine our position.

It is with great pleasure that I can testify to the accuracy and reliability of the maps furnished by the Engineer Department.

The descent to the valley of Davis' Creek was accomplished without

much difficulty. We found plenty of wood, some water which was quite alkaline, and some grass of a poor quality.

The march to the Little Missouri was resumed the next day. Davis' Creek is a very tortuous one, with high perpendicular banks. It is generally skirted with cottonwood, (some of large size,) willow-brush, and sage-brush of small growth. Plenty of good grass was found all the way. The bed of the stream varies in width from about 15 to 70 feet, the bottom being a miry, sandy earth, with occasionally a slight layer of gravel. The water was generally yellow and alkaline. The slopes and peaks of the valley are covered with a light growth of grass. One of the guides stated that when he passed down this valley with General Sully, in 1864, there was no vegetable growth; and Lieutenant Chance, Seventeenth Infantry, states that in 1872 no work was required to cross the train. In a distance of 8 miles, ten crossings were made, at the expense of much time and labor. As we drew near to the Little Missouri the aspect of the country changed for the better. The hills had a thicker and brighter covering of grass. The timber and brush became more luxuriant, and now and then were found fine springs of clear cold water. We were greatly troubled with mosquitoes until the parking of the train at the Little Missouri, where we arrived about 9 a. m., May 29. In the march down the valley of Davis' Creek, twelve crossings in all were constructed. The camp was established in a plain bounded on three sides by high hills, and having between it and the river a belt of fine timber about 200 yards in width. Game abounds in this section of the country and the river is well stocked with pan-fish. The river at high-water stage is about 200 yards wide from bank to bank. At the time we crossed, it was about 100 feet in width and from 2 to 3 feet deep, with a hard gravel bottom. The portions of the bed not covered with water were very soft and required much work to make them passable for the train.

Leaving the Little Missouri on the morning of May 31, the route lay in the bed of a small creek for about half a mile and then led over the bluffs. This latter portion of the route was very difficult of passage and required much and extensive work in the way of cuttings. The train, however, passed with but two upsets, and, considering the nature of the road, with remarkable speed. We reached the base of the more eastern of Sentinel Buttes about 7 miles from camp, and skirting this butte we passed over a very rough but well-grassed country and descended through a deep and difficult ravine to an open valley through which ran a stream of then small proportions on which we encamped. Rain fell during the evening, but changed into snow, and at 3 a. m. the next day several inches of snow had fallen, and the storm was severe. The little stream of the day before had swollen to quite important dimensions. Wood was scarce and not easily accessible. The animals suffered from exposure and want of grass. Two Big Horn sheep were killed by Reynolds on the road to this camp.

We left this camp on the morning of June 3, and a cold and disagreeable march of about 6 miles brought us out into a beautiful rolling prairie full of game. Before reaching the prairie we passed numbers of well-wooded ravines. Here we met scouts sent by the commanding officer of the Montana column, who brought information that their column had seen several parties of Indians, numbering from about twenty to fifty. These Indians were bold enough to assemble on the bluffs on the south side of the Yellowstone and dare the troops on the other side to an encounter. After a march of 25 miles, the longest yet made, we encamped on Beaver Creek. Beaver Creek at this point is about 30 feet

wide, with a depth varying from 1 to 6 feet, and the water is cool and clear. The banks are covered with a thick growth of brush. The bed of the creek is soft and muddy. There was wood in plenty and the grazing was excellent.

The next day, moving almost due south, we crossed a low "divide," from which rose here and there bare rugged buttes capped with masses of rusty sandstone, into the valley of a tributary of Beaver Creek. Crossing the stream by bridge we passed over a rolling, well-grassed prairie to another branch of Beaver Creek, which was found to be timbered, but the water was in pools. Thence we moved in a southerly direction over a barren country to a rocky "divide," along this divide for about 3 miles, and then changing the route to west of south, we encamped on Beaver Creek. The water here was in pools. Plenty of wood and good grass were obtained. Antelope and rabbits were the only game seen during the day, but large numbers of these were passed.

Bridging the creek early the next morning, the command crossed a rolling country, which had a fair soil and a good growth of grass on the higher portions. It was, however, intersected by numerous "coulées" and ravines. Reaching the "bad lands" at the head of Cabin Creek, we encountered a steep descent to the valley. Great difficulties presented themselves to the advance of the wagon-train. The valley was narrow and of a soft alkaline earth with deep washouts. The ridges or bluffs had a thick growth of small pine. Worrying through this bad-land region, and crossing three different branches of Cabin Creek, we finally reached a beautiful rolling prairie with fine grass. Some pools of snow-water were discovered, and camp established.

The alkaline bottom-lands traversed during the march were strewn with fragments of satin gypsum, which glistened in the sunlight and relieved somewhat the barren aspect of the scene. First-Sergeant Hill, Company B, Seventh Cavalry, informed me that while hunting he had seen a bed of lignite burning. His attention was attracted by seeing smoke issuing from a level spot of alkaline ground. Approaching, he saw a fissure about 10 feet long and 4 feet wide with radial arms. Smoke issued constantly, with now and then a puff of thicker, blacker quality. The earth crumbled and fell into the fissures, the latter gradually enlarging. There was no noise or upheaval.

The march to O'Fallon's Creek was over a country similar to that passed the day before. This creek was found to be about 30 feet wide, with a soft, muddy bed and good clear water. It was well timbered, many of the trees being of large size.

The march of the next day carried us into a region which, it is believed, was never before traversed by a wagon-train. Starting at the usual hour, we ascended the bluffs immediately west of camp, and found before us a very rough and uninteresting country. The land appeared to be entirely worthless. The monotony of the march was rendered still more dreary by a cold, drizzling rain, which lasted until the afternoon. The ascent to the "divide" was long, but gradual. The descent to the valley of the Powder was a difficult and delicate task, but we were more than repaid by the view which was unrolled before us as we reached the summit of one of the hills. The sight was one the remembrance of which will long linger with us. To our left was Powder River Ridge, with its fringe of pine trees. At our feet was the bad-land formation, with its deep, yawning chasms and its various-colored earths, fashioned into weird and fantastic shapes by the rains and floods. Leading up from these were long ravines, with their thick growth of timber, the dark, green hue of which formed a strong and beautiful

contrast to the softer and lighter shade of the grass-covered hills. To the right there stretched out a rolling country backed in the distance by the Yellowstone bluffs, whose rugged outlines stood forth in bold relief.

It was not until 7.20 p. m. that we encamped on the Powder about 20 miles from its mouth. The river at this point is 200 feet wide, and 2 to 3 feet deep. The water was very yellow, carrying a large amount of matter in suspension. The bottom is at places gravelly, with bowlders distributed over it; but at others it is a treacherous quicksand, demanding great caution in crossing. It commenced to rain about 4 p. m., June 9, and continued so to do until noon of the 10th. On the afternoon of the 10th, Major Reno, Seventh Cavalry, with six companies of his regiment, left this camp on a scout. Lieutenant Sturges, Seventh Cavalry, and Lieutenant Kinzie, Twentieth Infantry, were selected to keep a journal and itinerary of the march; but the latter commanded the Gatling detachment, and was too much occupied in keeping the gun with the cavalry to take any bearings. The former unfortunately had his note-book with him at the time he was killed.

We broke camp at 5 a. m., June 11, and commenced the march to the Yellowstone. For the first 5 or 6 miles the road was very rough, being over hilly ground, but after crossing the first creek we ascended to a beautiful plateau about 3 miles long. Two other plateaus, each between 3 and 4 miles in length, were traversed. They were separated by alkaline creeks with steep banks of soft earth. The bottom lands, like the valley of the Powder, were poor in grass, it being very thin and dry.

The ground was covered with sage, cactus, and prairie-dogs' houses. The hilly portion of the road was covered with drift, but this seemed to almost entirely disappear on reaching the plateaux. A march of 20 miles brought us to the northwest extremity of the last plateau, and from this point the Yellowstone and the Powder are both visible. From this plateau we descended to the open land formed by the junction of the valleys of the two rivers. It was found to be very soft, cut up by numerous gullies and abounding in sage, cactus, and rattle-snakes. Passing over the almost swampy portion we finally reached the banks of the Yellowstone, and found a spot sufficiently firm to enable us to establish camp.

The total distance marched up to this time was 318½ miles, with an average day's march of 15.9 miles.

The grass on the plateaus and in the swales leading down to the valleys was very fine. There was but little timber on any of the creeks, and that little was of small size. On the descent to the third creek we found some springs of very cold and clear water, but a decided alkaline taste was developed when the canteens became heated by the sun's rays.

The timber on the Powder diminishes quite rapidly as the valley is descended, but there is a thick grove on the Yellowstone at the mouth of the former stream. We remained in this camp until June 15, on which date Lieutenant-Colonel Custer, with six companies of the Seventh Cavalry and the pack-train, moved up the right bank of the Yellowstone. Lieutenant Wallace, of the Seventh Cavalry, was selected to keep the itinerary of the march. He did so until June 25. His report will be found annexed.

The Brigadier General commanding, with his staff, left the camp and proceeded up the Yellowstone on board of the steamer Far West. The Yellowstone is a river which has been described so often by different persons that any elaborate account of its valley would be but a tauto-

logical echo of the words of others. It will be sufficient to give but a general account of the state of the river at the time we ascended it.

The width varied from 200 yards to nearly 2 miles. The latter width was where the stream was divided up into narrow, rapid channels by numbers of islands. The water was very yellow, and held great quantities in mechanical suspension. The current was between 5 and 6 miles.

The first rapids we encountered were about 4½ miles above the mouth of Powder River, and the second about 23 or 24 miles above the same point. The channel was clear of islands until we reached Sunday Creek. Here the river commences to be studded at intervals with very beautiful timbered islands, on many of which we saw deer and elk. The water-level gradually fell during the season, and by the 1st of September the reef at Wolf Rapids was out of water, and impassable by the steamers. Navigation on this stream undoubtedly ceases at that time of the year.

About noon June 16 we arrived at the Seventh Cavalry camp, 2 miles below the mouth of Tongue River. The camp had been established on the site of an Indian burying-ground. We saw here quite a number of bodies. Some were found in trees, and others on the usual scaffolds erected by the Indians. I saw at this place the dead body of an infant about 10 months old in quite a good state of preservation. The skin was about the color of that of an Eyptian mummy, and was as well preserved as any mummy I ever saw. The face had been painted red. The hands were closed and bent upward and backward on the arms. The feet were similarly bent backward on the legs. This was probably due to the wrappings of calico and buffalo skins. The whole body was covered with what appeared to be a salt of lime.

Leaving this place June 20 we arrived at the camp of the Montana column about 11 a. m. the next day. Here we saw for the first time the Crow scouts. They were a very handsome set of men and appeared to be extremely good-natured. They greeted us with smiles and hearty "hows." They are much lighter in color than the Rees, and of larger size. They look very much more like warriors than any Indians I had hitherto seen, and their by no means inartistic dress adds much to their personal appearance. Their language is quite musical, especially when spoken by the women. It is not unlike Spanish in its general sound.

Leaving this camp we steamed up to the camp of the Seventh Cavalry, just below the mouth of the Rosebud. At noon the next day, June 22, Lieutenant-Colonel Custer with his regiment commenced the march which closed in the battle of the Little Big Horn, June 25. The report of Lieutenant Wallace, appended, contains the account of this march.

Early on the morning of the 24th we passed Fort Pease, which is situated on the left bank of the Yellowstone about 6½ miles below the mouth of the Big Horn. It consisted of a stockade with two block-houses, one at the northern and the other at the southern corner. It was established as a trading-post by a man named E. D. Pease, but the Indians continually harassed the garrison and killed quite a number of them. A battalion of the Second Cavalry was ordered to their relief last winter, and the post was abandoned. In the afternoon the troops were transferred to the right bank of the Yellowstone, and the march to the Little Big Horn was commenced.

I ordered Sergeant Wilson, with Private Culligan, to remain on the steamer, which was to ascend the Big Horn, for the purpose of making as accurate a survey as possible of the river, and collecting information in relation to the nature of the country. His report is appended with map.

The first march of 5 miles up the valley of the Big Horn brought us to Tullock's Fork, where we encamped.

At 5 a. m. the next morning the march was resumed. The route for the first 3 miles lay in the valley of the creek. The valley is very narrow, about half-a-mile wide, and of no value. The grass was rank and dry. The bed of the stream is about 30 feet in width. The water was found only in pools, and strongly alkaline. Leaving the valley we passed up and over the divide between this stream and the Big Horn. The country was very rough, with a miserable soil. It was a meshwork of ravines with steep sides. Pine trees were sparsedly scattered over the hills, and the ravines were thickly timbered. The grass was thin and short, and associated with large quantities of cactus and isolated patches of sage-brush. Outcroppings of sandstone were frequent, and every now and then we saw dislodged masses of this stone which had been weather-worn into curious and somewhat artistic shapes. Here and there we observed conical-shaped peaks of purely white alkaline earth entirely destitute of vegetation. As we drew nearer to the valley of the Big Horn the accidents of the land became much more decided. The "divide" became a sinuous backbone and the ravines much deeper and more ramiform. The sandstone occurred more frequently and in larger quantities. From this divide the snow-capped Big Horn Mountains and cañon and Pryor's Mountain were plainly visible, and at the foot of these the valley of the Big Horn gradually sloped down to the stream. That section of the country appeared to be much more open and extensive than any we had previously seen, and it it said to be a fine agricultural region. The whole surface of the divide was covered with drift, which contained many beautiful specimens of agates. The descent to the valley of the Big Horn was very precipitous and uncomfortably difficult. The sun seemed to concentrate its rays in this valley, and to absolutely pour down its heat. In addition, the air was thick with dust which seemed to overcome the senses. It was only when the sharp rattle of the snakes aroused the almost slumbering troopers that there appeared to be any life left in the column. The infantry particularly had a very severe march, as there was no water to be obtained. The latter portion of the journey was down the valley of a dry creek, and, after a march of 22 miles, we reached the beautiful and refreshing Big Horn. The river at this point was about 200 yards wide, with a swift current of clear, cool water. It contained islands which, like those of the Yellowstone, were thickly timbered, and had a carpeting of most excellent grass. Resting here for a short time, the command moved up the valley for a distance of about a mile and a half, when the infantry encamped in the thickly-timbered bottom. The Brigadier-General commanding with the cavalry pushed on, and a very disagreeable march we made of it. The night was cold and wet, and so dark that nothing could be seen at any distance in front of us. After much difficulty we succeeded in finding a creek which contained a pool of alkaline water, and the remainder of the night we passed in a slough of mud and disgust.

Breaking camp the next morning, we moved toward the Little Big Horn. Crossing a tributary of the latter stream, we ascended the high bluffs to the plateau above. Here the infantry rejoined us, and here for the first time we heard of Custer's fight. Two of the Crow scouts who had been sent with Custer were brought to the column by Lieutenant Bradley, of the Seventh Infantry. They reported that Custer's command had been "wiped out." This report was not believed at that time, and the command moved on. The country traversed before reaching the valley of the Little Big Horn was that of the usual description of

high lands west of the Missouri. Descending to the valley of the Little Big Horn we crossed that river about 9 miles above its mouth. The march was continued up the valley of this stream for a distance of 5½ miles. At this point we first saw hostile Indians. About 7 p. m., on this date, June 26, scouts came in with the report that they had been fired upon. A halt was ordered and on the hills in front of us were seen bodies of mounted men. As well as I could judge by the eye, I should say the nearest were within about 2 miles. They remained standing and regarding us intently. They were formed in regular order with one man a short distance in advance. They were at first supposed to be Custer's men, but Lieutenant Roe of the Second Cavalry was sent with one company to reconnoiter, and, on showing a white flag for a parley, was fired upon. The Indians slowly moved off in the direction of the Big Horn. We went into camp in the middle of the valley of the Little Big Horn, about 9 p. m. This valley is about 1½ miles wide; the soil is good and the grass very fine. There is but little cactus or sage. The stream varies in width from about 30 to 75 yards. The current is rapid; the bottom a fine gravel, and the water beautifully clear and sweet. It is well lined with timber, much of it being of large size. The next morning (June 27) we resumed the march up the valley. In moving over the hills about 2 miles from camp, we crossed the trail made by the Indians the night before. From these hills we saw two teepees in the valley beyond. Continuing the march we soon descended to the valley and arrived at the teepees, which were found to contain the dead bodies of Indians, and which were all that remained of what had been a large Indian village. Information was soon brought to us by Lieutenant Wallace that Major Reno with a portion of the Seventh Cavalry was intrenched on the bluffs. After a march of about 9 miles we encamped in the valley at the foot of the bluffs, which had been the site of a siege for nearly two days. We remained in this camp until the evening of the next day when the command was moved down the valley a distance of about 4½ miles.

The next day a survey of the field was made, and in the afternoon the command again moved with the wounded in the direction of the mouth of the Little Big Horn. News having been received that the steamer was at the mouth of the river, a night march was made, and at 1 a. m. all the wounded were safely and comfortably settled on board.

July 3 found us in camp on the Yellowstone about 3 miles below the mouth of the Big Horn. We remained in this camp until July 22, when the command was moved by Colonel Gibbon to a point a short distance below Fort Pease. At this latter camp the mosquitoes were almost intolerable. On the night of July 14 we were visited by a severe storm, and about 3 a. m. of the 15th the camp was flooded, the water being about a foot in depth.

On the 27th of July the command was moved to a camp opposite the Rosebud where Gibbon's command arrived July 30. In this camp we remained until August 6, on which date the forces, with the exception of the guard for the supply-camp, were crossed to the right bank of the Yellowstone. During this time the re-enforcements, consisting of six companies of the Fifth and Twenty-second Regiments of Infantry each, arrived. In the mean time, also, the battery had been changed, two 3 inch rifles and one Napoleon having been substituted for the Gatlings.

On August 7 we experienced the warmest weather of the season, the thermometer reaching 110° in the shade.

At 5 a. m., August 8, the command commenced its march up the valley of the Rosebud. The stream is well timbered near its mouth, but

the grass is poor, and the water was unfit for use. As we advanced up the valley it became narrower and thickly timbered, with plenty of grass, but not of a very good quality. There was but little water in the stream and that was bad along the whole distance traveled by us. The valley consists of alternations of bad lands and narrow reaches of bottom-lands covered with grass, rose-bushes, juniper, and cottonwood. Great quantities of dead timber were found strewn over the ground. The first day's march was severe as the weather was very warm. The next day we were visited by a very cold rain, but August 10 was delightfully cool and pleasant. We passed the sites of three old Indian c mps. During this march of 36½ miles twenty-one artificial crossings were constructed and much road-cutting was also necessary.

About noon, August 10, we met the command from the Department of the Platte, and the two forces encamped together that night on the Rosebud.

At 11.30 a. m., August 11, the two commands started on the Indian trail. The wagon-train was sent back to the supply-camp on the Yellowstone, and the pack-mules were again resorted to.

Leaving the valley of the Rosebud and ascending the hills, we found before us an excellent grazing country. The soil was poor, being often of a decided red, giving up clouds of dust; and yet the grass was fine and of most luxurious growth. The usual covering of gravel was present, and the descent to the Tongue was very steep and difficult, the earth being very loose and full of pebbles, bowlders, and detached pieces of shale. The Tongue was crossed after a march of 10 miles in an almost due easterly direction. The river was at this point about knee-deep, beautifully clear, and with a firm gravel-bed and rapid current. The water was cold and sweet.

A march of a few miles down the valley brought us to the camping-place. The grass was very rich and in profusion, and there was plenty of cottonwood interspersed here and there with ash of small size. A heavy and continuous rain fell during the night, and as no tents were allowed everything was drenched. The rain continued until about noon the next day, when the mules were packed with their soaked loads, and the journey down the valley of the Tongue was recommenced. For a distance of about 10 miles along the route the valley is not only picturesque and varied as to its scenery, but of excellent quality as to its soil. The grass was the finest that had yet been seen by us, and while the valley itself is capable of being converted into fine gardens, the grazing upon the hills and high lands made it appear to be, with the exception of the Yellowstone, the most desirable portion of that section of the country. The only game were ducks, geese, and sage-fowl. This was probably due to the fact that the Indians had passed up and down the valley. There was some pine on the hills and in the ravines.

The trail which we had been following was large and the evidences of trains having passed were marked and numerous, but they were not, as afterwards proved, of very recent date.

At a distance of about 13 miles the nature of the valley had gradually changed. The timber had become of poorer quality and much more scarce. The soil became of much less value; the ground was cut up by deep and frequently occurring ravines, and the banks of the river became higher and steeper. The usual accompaniments of uninteresting land, sage and cactus, appeared in unwelcome frequency and profusion. Large amounts of lignite were seen in the deep washouts, and at times the road became rather dangerous on account of the subterranean pas-

sages leading from these washouts to the river. The rain continued all night.

The sun shone brightly the next morning, Sunday, August 13, but it again rained during the night. The nature of the valley was similar to that already described.

The next day's march brought us to our camp on Pumpkin Creek, a tributary of the Tongue. The valley of this creek is of the same description as that of the Tongue; only being one of the third order, it is smaller. The stream was well wooded. The bed was hard gravel, but in consequence of the late rains the water was simply liquid mud. Fortunately springs were discovered. Rain fell during the night.

The next day the route lay over a very broken and sterile country; in fact for some miles it was of the pure and unadulterated "bad-land" nature. Crossing the divide we traveled along the valley of a small creek, a tributary of the Mizpah, and thence we descended to the valley of Powder River, striking the latter just where it receives Mizpah Creek. It rained for four hours that afternoon.

In consequence of the poor condition of the horses, both commands left this camp the next day and marched down to the Yellowstone, arriving there on the afternoon of August 17. We found that the Indians had burned much of the grass.

We remained near the mouth of the Powder in a very disagreeable camp on the bare sand until August 25. During that time we were visited by two cold and severe rain-storms, which flooded the infantry camp.

August 25, we marched up the valley of the Powder again to find the Indian trail and follow it. That evening one of the scouts brought news that the boats had been fired into at Glendive Creek. The next morning the command from the Department of the Platte followed the Indian trail. The Brigadier-General commanding this Department, accompanied by his staff and one company of the Second Cavalry, returned to the boats at the mouth of the Powder. The remainder of the troops, under command of Colonel Gibbon, marched down to a point on the Yellowstone about 2 miles below the mouth of O'Tallon's Creek, where they were crossed to the north side of the river by the steamers which had descended the stream for this purpose. About dusk the same day, August 27, the command moved up the valley of a dry creek, and encamped, without wood or water, after a march of 6½ miles.

The next morning we crossed in an almost due northerly direction to Bad Route Creek, where delightful water was found, and we were enabled to break our fast.

Moving out from this halting-place, we followed up the "divide" of Bad Route Creek. The grazing was good, but the ground appeared parched and dry. There was very little water, and no timber was seen except on the stream and its tributaries. At a distance of about 13 miles from our camp we halted at the headwaters of one of these tributaries. Here we found the grass very fresh and green, and the ground sown with flowers of divers and beautiful colors. The rose-bushes with their bright-red berries, the large cottonwood, and the straight ash, added their charms and the comfort of shade to the scene. Springs of clear, cold water were discovered. A farther march of 8 miles brought us again to Bad Route Creek, where we found excellent water in pools, plenty of wood, and good grass. During this last part of the day's march all who were mounted were attacked by swarms of winged ants. Strange to say, the infantry were not troubled by them.

The next day, August 29, we traveled northward towards the Mis-

souri-Yellowstone "divide." When near the "divide," we ran into a herd of between 2,000 and 3,000 buffalo. Great numbers of antelope also were seen.

Upon reaching Clear Creek we turned southeast, and after a march of about 7 miles down the valley of the creek we encamped near some pools of most villainous water. Attempts were made by digging to obtain water which would be free from any taste or odor of the buffalo, but only partial success was attained. Up to this point the country had been a most excellent grazing one, and is easily practicable for a wagon-train, with the exception of a very narrow stretch of "bad-lands," about 8 miles from the Yellowstone. But even this could readily be made so. It is believed that a wagon-train could travel northeast from the Yellowstone to the Missouri without trouble, saving, perhaps, that to be encountered at the bluffs of the Missouri. One very delightful change which we experienced in crossing this section was the almost total absence of sage or cactus.

Leaving Clear Creek and traveling in a direction a little north of east we crossed the small streams which unite to form Spring Creek. We found in them very good water in pools. Leaving these latter streams the country gradually changed, the alkaline formation became more apparent, the grazing became more scarce and of inferior quality. Positively defined bad-lands made their appearance as we neared Deer Creek, and extended to the creek itself. The upper portion of this creek is very narrow, with low bottom-lands of slight width. The stream had a reddish hue, due to vegetable matter in the bed. The timber on the creek commences about 2 miles below where we encamped. There were quantities of bullberries growing on the banks. These berries are about the size and of the color of currants, and have very nearly the same taste. At that time (before frost) they had quite an astringent, acid taste. The bush is a thorn, with olive-green, elongated elliptical-shaped leaves. The bush grows as high as 20 feet, but the average height is about 10 feet. These berries furnished us at that time with an acid which satisfied a craving that had possessed us for some days.

The next day's march was down the valley of Deer Creek. This valley is very confined and utterly worthless, except in spots, where grazing is fair; but even here the spear-grass is abundant. The bench is narrow, and the bad-lands commence on each side at the edge of the bench. The only timber is cottonwood and ash, and very little of these, except within about 3 miles of the Yellowstone, where the stream commences to be thickly timbered. The bed is gravel and clay. The water was found in pools, but was not unpleasant except near the Yellowstone. Sage and cactus were found in profusion. A few ducks but no other game of any description were seen. Rattlesnakes infested the whole valley. The command remained in camp opposite Glendive Creek until September 6, when the Fifth Infantry were sent to Tongue River, and the Montana column commenced its homeward march.

The Brigadier General commanding, with his staff, arrived at Fort Buford September 7, and receiving orders to return to Saint Paul, my connection with the troops in the field ceased on that date.

RÉSUMÉ.

The geological information obtained on this campaign is very meager, as would naturally be expected. The expedition having been purely a military one, escorts could not be furnished for examination of the country at any great distance from the trail, and, in addition to this, the

crossing of streams and road-making required so much attention and time, that but a cursory examination even of the trail could be made. In fact, any full report of the geological formation of that region would contain nothing new, as Warren, Raynolds, Ludlow, and others have submitted very exhaustive reports on that subject. It is sufficient, in dismissing this subject, to say that the little knowledge gained is dotted here and there through the body of the report.

Agriculturally considered, the different sections of the country traversed can be classified into but two grades, fair and worthless. The fair sections are of the same quality as the land immediately around Fort Lincoln and Bismarck. The soil is a sandy loam with a sub-soil of clay.

The following information, which I received from Mr. Kellogg, a correspondent of the New York Herald resident in Bismarck, may convey some slight idea of what such a country is capable of producing.

In reply to questions concerning the land around Bismarck, I learned that vegetables grew very finely. Potatoes of the season of 1875 were very large; picked ones measured 12 to the bushel. Cereals have not been extensively tested, but Omaha and Indian corn grow finely, and white dent very well. Hay is taken from the bottom-lands and swales, the former yielding about 2 tons, and the latter from one-half to 1 ton to the acre. Cottonwood is the almost universal timber. A species of pine is found on the hills and in the ravines leading down from them, but it is of light growth. Sergeant Wilson, of the engineer detachment, reports that he saw quite a large amount of pine in the valley of the Big Horn, ranging from about 1 to 1½ foot in diameter. Occasionally box elder, ash, and scrub-oak are encountered in small quantities. The timber is confined almost entirely to the stream-bottoms and to ravines, and is seldom found to extend more than a few hundred yards from the water's edge.

The winters are long, with 5 months of cold weather, the mercury often standing at 39° plus below zero.

Another great drawback is the universally conceded slight rain-fall. I learn that it is about 8 inches, and mostly confined to the spring. This has been stated by so many that I suppose it must be true, but during last summer fully 6 inches of rain fell. This amount is a mere matter of judgment on my part, as I had no instruments by means of which the true amount of fall could be ascertained. Even after heavy rains the soil rapidly becomes dry and crumbly, but this may be due to the fact that it has not been turned or broken.

The question of the feasibility of sufficient irrigation I am not prepared to discuss. The water is universally what, in the common parlance, is termed "alkaline." The different streams are all of the same nature, differing from each other only in a quantitative composition. I brought with me to Saint Paul tightly-corked samples of the Yellowstone, Powder, Tongue, and Rosebud waters. It is found, from the qualitative analysis which my private means would allow me to make, that they are, as stated above, similar each to the other, containing sulphate, carbonate, and chloride of lime, magnesia, carbonate of soda, (?) and chloride of sodium. The tests for nitrates and iron gave no results. The amount of substances held in mechanical suspension, (silicates and clay,) as well as of the organic matter, is great. From the slow rate of precipitation by permanganate of potash, it is presumed that the organic matter is largely, if not entirely, vegetable. On uncorking the bottles the odor of sulphureted hydrogen was very strong. The corks were found to be blackened and covered with the superincumbent white deposit which all sulphur-waters produce. I have neither the experience

nor the means to enable me to make a quantitative analysis, and am limited in this regard to saying that only the Rosebud and Powder, of the larger streams, have a perceptible alkaline taste—the latter being simply perceptible, and the former repulsively strong. Numbers of the smaller streams, such as Tullock's Fork, are very bad in this respect.

The country generally affords excellent grazing. The high lands have a fine growth of buffalo and bunch grass, and the bottom lands, in addition to these, have the favorite of the stock, the beautiful gamma, and a jointed grass which the horses devoured with avidity. In some valleys there is to be found a small amount of wild rye. Sage and cactus meet the eye at almost every step, and occasionally a running vine-like growth of juniper is encountered. Hordes of grasshoppers almost every season infest the whole region.

The planting of trees has been commenced in Dakota along the line of the Northern Pacific Railroad, and has so far been successful. There is no reason why similar success should not be obtained farther west.

As a summation, I should say that, in the terms of the classification mentioned above, the valleys of the Yellowstone, Big Horn, Little Big Horn, and Tongue are fair, and those of the Rosebud, Powder, Little Missouri, and Tullock's Fork, so far as traversed, are worthless, and are to be regarded only as places where venomous snakes may fitly knot and gender.

The amount of astronomical work accomplished during the season was but small. This was due to bad weather early in the season and later to the want of transportation for the instruments. It cannot be expected that on a campaign against hostile Indians, when it is difficult to obtain transportation for even the indispensable articles pertaining to an armed force, chronometers and instruments can be carried. In addition to this, when pack-mules are used, the line of march is not as carefully selected as if the column were attended by a wagon-train, and consequently it is believed that the rates of the chronometers would be so irregular, that unreliable results would be obtained. Therefore, the instruments were left on the steamer at the time when pack-mules were substituted for the wagon-train as the means of transportation.

Observations were taken May 11, at Fort Lincoln, to determine the error of the chronometers. At the following places also observations were taken: May 23, Young Men's Butte; May 25, North Fork of Heart River; May 29, Little Missouri River; June 3, Big Beaver Creek; June 8 and 10, Powder River; June 12 and 14, Yellowstone River; June 16 and 18, mouth of Tongue River.

In crossing the bad-lands immediately west of the Little Missouri, the chronometers "jumped," and, on account of the bad weather noted in the body of the report, it was impossible to detect the fact until too late.

As the longitude-determinations depended entirely upon the differences of chronometric errors at Fort Lincoln and at the new points, the observations west of the Little Missouri are valueless.

Annexed will be found a table giving the times of departure and arrival, the barometric and thermometric readings, with the resulting elevations, the distances traveled as indicated by the odometers, and the few latitude and longitude results obtained.

It is thought that a few remarks in reference to one serious defect in the organization of the columns operating in the field during the campaign will not be out of place.

That defect was the absence of a good bridge-train. On leaving Fort Lincoln there were placed under my orders two wagons containing tools and some 1½-inch pine plank, and some 2 by 4 and 3 by 6 pine pieces.

Fig. 2.

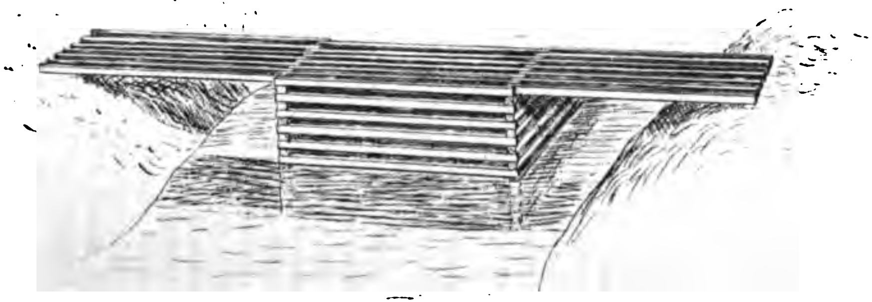
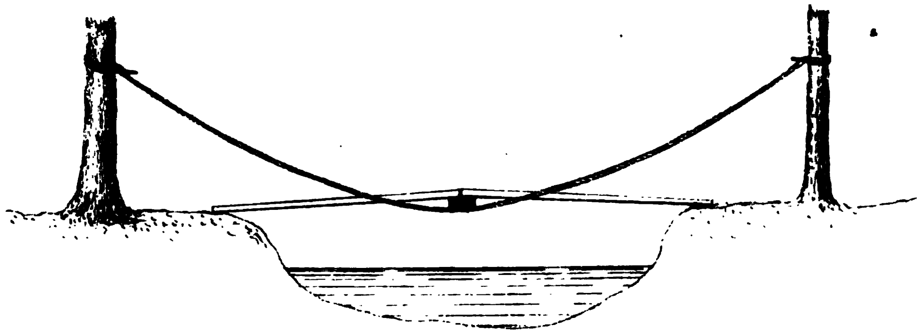


Fig. 3.



This crude bridge-material had been collected by the post quartermaster, Capt. H. J. Nowlan, Seventh Cavalry, and the very fact that though simple it was of incalculable benefit only shows how useful and valuable a small canvas ponton-train would have been. I am free to say that I think no supply-train should be sent into that western country without at least two trestles, four canvas pontons, and the accompanying bridge material. Four pontons are estimated, because a substantial raft could be made of that number for crossing the larger streams. If these could not be obtained from the regular engineer depot, the Quartermaster's Department should be called upon to construct them in accordance with proper plans and specifications.

Last season the material mentioned above saved the column many miles of hard marching and great loss of time, but, unfortunately, the supply was soon exhausted, and it then became necessary to resort to the long, tedious, and uninteresting operation of filling in the bed of the stream to be crossed. It is thought, also, that there should accompany each column a detail of men whose sole duty should be to construct and care for the bridges. Much time would be saved by thus having men who would be familiar with the work, and who would take a greater interest in it than can be expected of those who are detailed from day to day.

The wagon-train made 59 crossings in all, and the average time consumed in making these crossings was 40 minutes each. As a matter of interest, there will follow a description of some of the methods of crossing streams which have been or can be employed by our troops in the western country.

1st. By filling in the bed of the stream or ravine with logs, covering these with a layer of brush, and in turn covering the brush with a thick layer of sod or earth. It is very seldom that the time can be allowed for carrying this structure high enough, and consequently the approaches must be cut quite deep; and experience has shown that there is not more than one teamster in twenty who will not let his team run down the slope of the approach, and strike the causeway with a heavy thud, thus breaking through the road bed and requiring constant work of refilling. The brush used may be sage, willow, and young cottonwood. The sage is by far the most easily manipulated and the most enduring. Logs, to act as side-rails, should be laid, and the roadway should be at least 15 feet broad. The axes of the approaches and the crossing should be in the same plane, perpendicular to the axis of the stream. This would seem a trivial remark, but it was observed last summer that, unless closely watched, the men would, unconsciously, deviate from the proper direction, and the crossing would be oblique to the stream. Whenever that happened, there was trouble with the teamsters.

2d. By making a crib-work of spare wagon-tongues, and laying others covered with sod to form the roadway. The wagon-pole is of oak, and 10.7 feet long. (See Fig. 2.)

3d. By employing the bull-ropes or fifth-chains as suspension-cables, and laying at the bottom of the catenary three or four wagon-tongues to act as a species of girder. The flooring is laid with other wagon-tongues, and the whole covered with sod. To prevent swaying, lariats may be fastened to the ropes and anchored to the shore. (See Fig. 3.) This method is, of course, limited to timbered streams and to those which are a little less in width than twice the length of a wagon-tongue, or 21 feet.

4th. By employing floating piers, each consisting of a wagon-body placed over the number of empty water-kegs that can be confined with-

in the body. The roadway, as before, is formed of wagon-tongues. Lariats can be used as anchoring-cables for the piers.

To determine what weight, approximately, will be borne by such a pier, the following formulæ will be used:

$$W = (v \times 62.5 \text{ pounds}) - K.$$

$$\frac{a+b}{2} = d \quad v = \frac{\pi d^2}{4} \times l = \pi l \left(\frac{a+b}{2}\right)^2$$

in which

W = weight in pounds which a keg will bear.
K = weight in pounds of the keg.
v = volume of the keg in cubic feet.
l = length of the keg.
a = diameter at bung.
b = diameter at end.
d = mean diameter.

The values which follow were determined for the 10-gallon keg, by Lieutenant Nave, Seventh Cavalry, and Private Goslin, Engineer Battalion.

$K = 21$ pounds. $\quad \frac{a+b}{2} = \frac{1.372 + 1.02}{2} = 1.196.$

$l = 1.708$ feet.

$a = 1.372$ feet. $\quad v = \pi b \left(\frac{a+b}{2}\right)^2 = 3.1416 \times 1.708 \times (1.196)^2$

$b = 1.02$ feet. $\quad v = 7.6754$

$W = (7.675 \times 62.5 \text{ pounds}) - (21 \text{ pounds}) = 479.69 \text{ pounds} - 21 \text{ pounds} = 458.69$ pounds.

That is, each keg is capable of sustaining a weight of 458.69 pounds.

The interior dimensions of the 6-mule army-wagon body are as follows: depth, 2 feet; length, 10 feet; width, 3.58 feet.

Fourteen 10-gallon kegs will about fill a wagon-body of the above dimensions; and hence each set of kegs will virtually sustain a weight of fourteen times 458.69 pounds, or 6,421.66 pounds. Subtracting from this the average weight of the body, (423 pounds,) we shall have 5,998.66 pounds as the weight which can be borne by each pier.

The dimensions of the wagon-tongue are as follows:

Length of tongue=	10.7	feet.
Breadth at point=B′=	2.5	inches.
Depth at point=D′=	2.5	inches.
Breadth at butt=B″=	3.88	inches.
Depth at butt=D″=	2.75	inches.
Mean breadth=B′=	3.19	inches.
Mean depth=D′=	2.625	inches.

Supposing the tongues not to lap on the piers, we shall have for the length of tongue between supports

$$L = 7.12.$$

Substituting these values in the formula for a beam resting upon two supports, or

$$W = \frac{6 k B D^2}{L}$$

we shall have

$$W = \frac{319 \times (2.625)^2}{712 \times 12} \times 1200$$

Fig. 4.

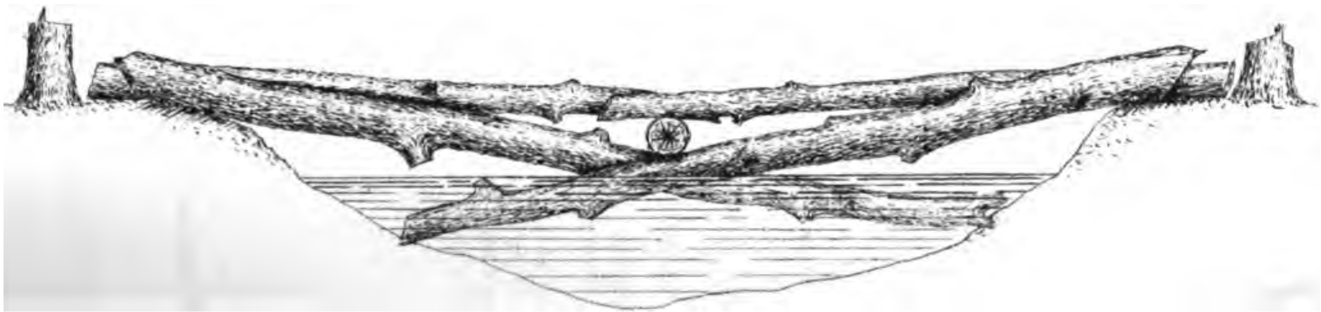


Fig. 5.

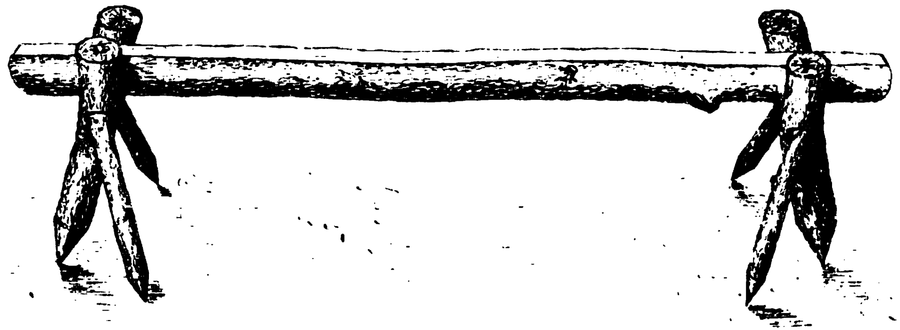


Fig. 6.

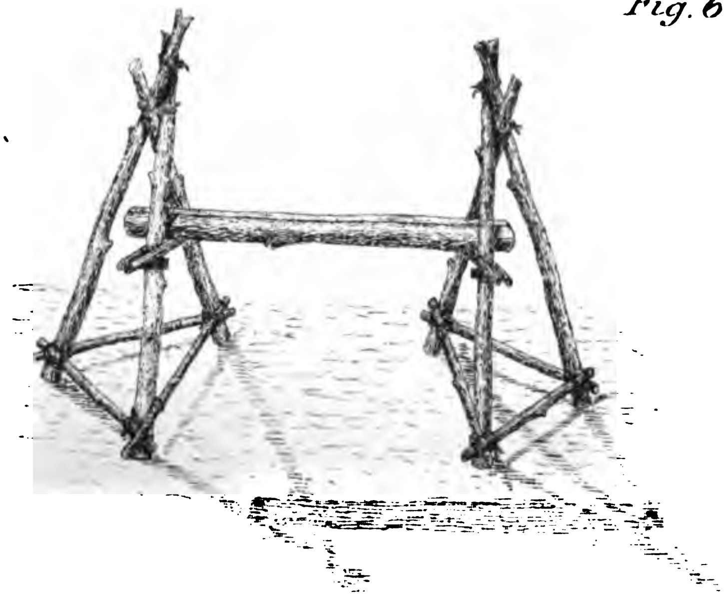
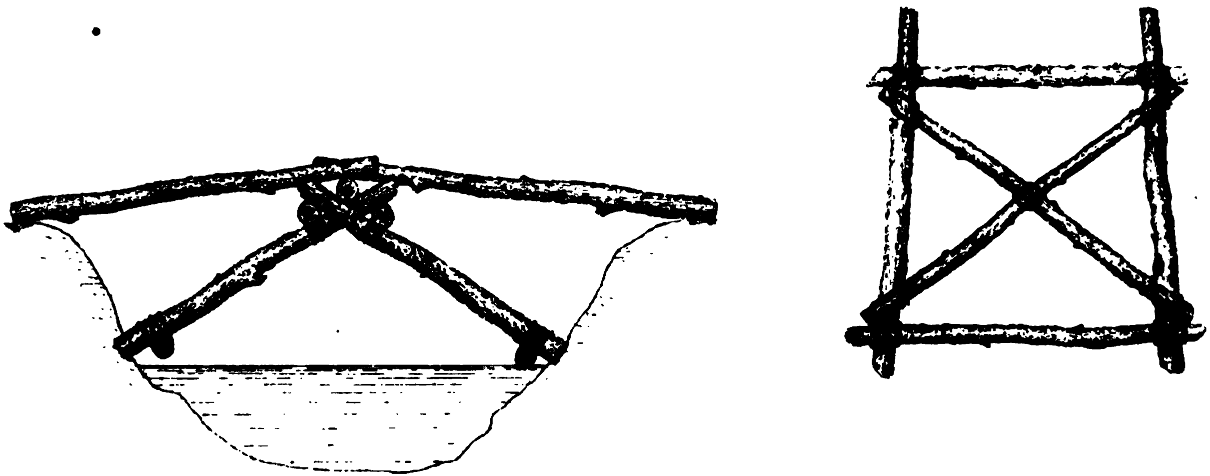


Fig. 7.



or

$$W = 308.8$$

and dividing by 4, the factor of safety, we have

$$W = 77.$$

The average weight of the army-wagon is 1,800 pounds, and assuming the weight of a mule as 1,000 pounds, we shall have 7,800 pounds as the weight of the wagon and 6-mule team. Assuming, now, the average weight of load to be 4,000 pounds, we shall have 11,800 pounds as the weight on the bridge.

The total length of bridge occupied by wagon and team is 49 feet, and consequently the load per running foot is 241 pounds, nearly. Referring to the breaking weight of the tongue, we see that 4 tongues laid as balks are sufficient; 40 tongues will be required for flooring, if laid close. There will then be in all 44 tongues, weighing 28 pounds each. In other words, each bay, exclusive of the piers, will weigh 1,232 pounds, or 115.1 pounds per running foot. We have as the weight of 49 feet of bridge, with load, 11,800 pounds plus 115.1 pounds × 49, or 17,440 pounds, nearly. This weight will be borne by at least five piers. But we have seen above that each pier will support 5,998.66 pounds, and consequently five piers would support 29,993.3. In other words, the bridge would have nearly double the strength absolutely necessary. It is also to be seen that any field-battery can be crossed on such a bridge. A similar bridge can be constructed by using simply the kegs, lashed together, for piers; but the other method is preferable, as the wagon-body keeps the kegs together, besides furnishing a level bed on which to lay the balks.

5th. By felling four trees, which, with the butts resting on the banks, will, by crossing each other two and two, form supports for a girder and then laying a flooring. They should either be spiked or lashed together where they cross. (See Fig. 4.)

6th. By forming rude trestles, which may be either simply notched, or, what is better, spiked with lariat-pins. (See Fig. 5.) The girder-timbers can be squared off on the upper side and the stringers be notched so as to hold better. The main pieces of the legs may be anchored to the shore by lariats. A tripod trestle-bridge can be formed of simple tripods connected at the bottom by braces. A bar is lashed or pinned across two legs of the tripod, and on this rests the cap-piece, as in the figure. (See Fig. 6.)

7th. By various combinations of saplings forming what are termed single or double lever bridges.

A small work on Field Fortification by Maj. W. W. Knollys, F. R. G. S., Ninety-third Sutherland Highlanders, contains a very good description of such bridges, and is inserted below:

A single-lever bridge is composed of two frames which look into each other. (See Fig. 7.) A full-sized section of the stream or gap should be first traced on the ground. The line representing the breadth should be bisected. Two standards should then be laid down on the section and on them marked the places where the main transoms, the fork transom, and the ledges will come. The frames should then be constructed. These distances should be between standards at the transom 9 feet 6 inches and at the ledger 10 feet 6 inches. In the other frame the distances should be 11 feet and 12 feet, respectively. As the frame lies on the ground with its butts toward the stream the transom should be

under and the ledger above the standards. The diagonal dimensions of the frames are measured to ascertain whether the positions of the pieces of the latter have not changed. Of the diagonals, one is altogether above the frame; the other has its butt over and its top under. The diagonals are lashed to each other where they cross, and also to the standards. The frames are raised and lowered into their positions by means of foot and guy ropes. The pickets for the foot-ropes are driven into the ground about two paces from the edge of the bank and four paces on each side of the center of the frame. The foot-ropes are attached to the butts and passed twice around the pickets. The pickets for the guy-ropes are driven in about twenty paces from the bank and ten paces from the central line. The fore and back guys are fastened to the tips, the ends of the fore guys being thrown across the stream and those of the back guys being passed twice round their respective pickets. The frames are then raised by hand and carried to the edge of the bank. The butts are then gradually lowered into position, one frame being hauled over till it is a little beyond the perpendicular, in which position it is secured by fastening the back guys to their pickets. The other frame is dealt with in a similar manner. Both frames are then lowered till they interlock. A spar is laid across the fork formed by the crossing of the standards, to serve as a support to the road-beams. The roadway is composed of balks lashed to each other, and covered with planks, spiked or rack-lashed down, or by fascines covered with loose brushwood, earth, or heather. The ends of the balks should be attached to a beam or stout spar half buried in the ground and picketed down, its direction being perpendicular to the length of the bridge. It is desirable to place rails or breast-lines at the edges of the bridge. At each transom the road-beams should be all tips or all butts, and the ends of each pair should be lashed together. It must be noted that the frames should not make a greater angle with each other than 120°.

A double-lever bridge is formed in a manner similar to that in which a single-lever bridge is constructed, with the exception that the two frames do not cross each other, but are connected by means of a second frame, which has no diagonals. (See Fig. 8.)

Double-lever bridges are suited for openings of 40 feet. Even openings of 60 feet have been spanned by a double-lever bridge.

Another combination can be made forming a lever truss bridge. The frames are made as in the case just cited, but an extra support is given to the roadway by the rope at the center. The figure explains itself. (See Fig. 9.)

Appended will be found a copy of the journal kept by Second Lieut. E. J. McClernand, Second Cavalry, acting engineer-officer of the Montana column. His topographical work has been incorporated in the general map.

I am indebted to Mr. W. H. Wood (formerly assistant engineer in this office) for the admirable drawings, which accompany this report.

Very respectfully, your obedient servant,

EDW. MAGUIRE,
First Lieut. Corps of Engineers,
Chief Engineer Department of Dakota.

The ASSISTANT ADJUTANT GENERAL,
Department of Dakota.

Fig. 8.

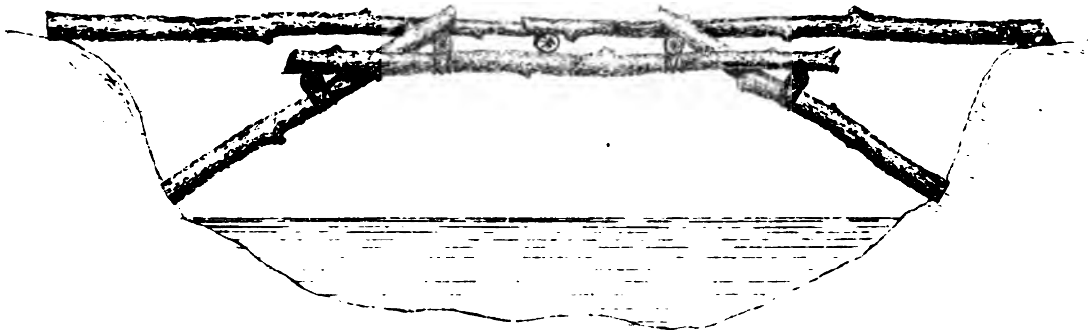
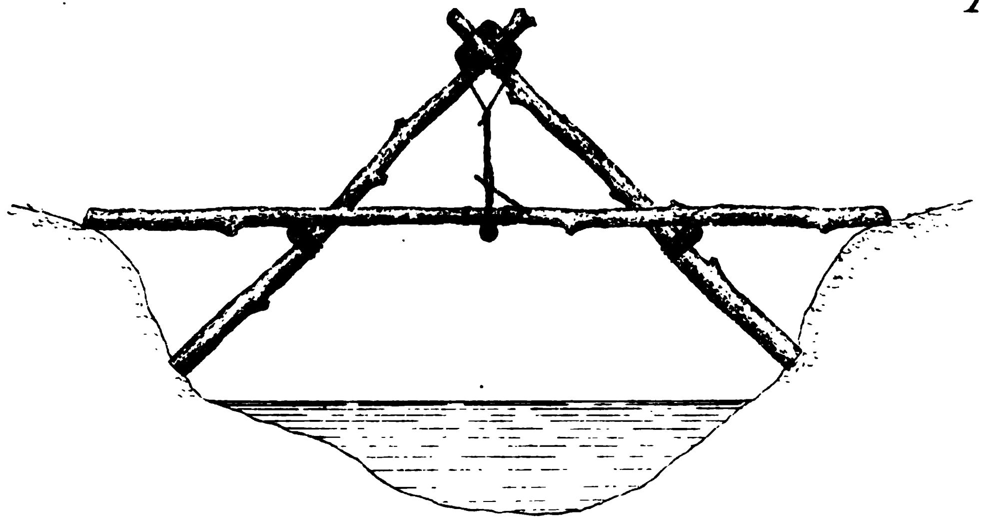


Fig. 9.



Summary table of daily instrumental observations, with deduced altitudes, latitudes, and longitudes, distances traveled, &c.

Date.	Location.	Start.	Arrive.	Thermometer.					Barometer.		Elevation.	Latitude.	Longitude.	Day's march.	Total distance.	Weather.
				Maximum.	Minimum.	Number.	Total.	Mean.	Evening.	Morning.						
		A. M.	*P. M.*	°	°			°	*Inches.*	*Inches.*	*Feet.*	° ′ ″	° ′ ″	*Miles.*	*Miles.*	
May 17	Fort Abraham Lincoln	4.30							28.13	28.00	2,211					
17	Heart River		1.15	73	45	16	983	61.4	27.47	27.65	2,379			13.40	13.40	Rain.
18	Near Sweetbrier Creek	4.35	1.45	74	56	20	1,308	65.4	27.26	27.32	2,815			10.80	24.20	Rain.
19	Crow's Nest	4.25	11.40 a.m.	69	58	15	958	63.8	27.31	27.62	3,147			13.50	37.70	Rain and hail.
20	Tributary of Heart River	7.25	1.30	60	55	6	354	59.0	27.76	28.03	2,813			9.50	47.20	Rain.
21	Branch of Mud Creek	6.30	3.50	66	53	10	580	58.0	27.96	27.91	2,545			13.33	60.53	Clouds.
22	Thin-faced Woman's Creek	4.25	1.00	64	44	12	645	53.7	27.67	27.55	2,505			15.25	75.78	Clouds.
23	Young Men's Buttes	5.00	8.40 a.m.	61	48	8	432	54.0	27.66	27.62	2,841		102 15 10.7	7.70	83.48	Clouds.
24	Branch of Heart River	4.15	2.10	75	44	17	1,044	61.4	27.32	27.35	2,796			19.12	102.60	Clouds.
25	Branch of Heart River	4.15	2.40	74	48	13	845	65.0	27.18	27.15	3,100	46 54 27.8	102 59 04.7	19.72	122.32	Clouds.
26	Branch of Heart River	4.40	2.10	79	55	11	813	74.0	27.04	27.03	3,279			12.40	134.72	Rain.
27	Davis Creek	4.30	2.25	81	53	16	1,129	70.5	27.25	27.05	3,416			17.00	151.72	Clouds.
28	Davis Creek	4.25	12.00 m.	80	58	7	462	66.0	27.20	26.87	3,301			7.75	159.47	Rain.
29, 30	Little Missouri River	4.10	9.00 a.m.	74	65	7	490	70.0	26.67	27.44	3,252	46 51 09.5	103 31 20.7	6.40	165.87	
31, June 1, 2	Near Little Missouri River	8.00	2.00	65	58	11	677	61.5	26 67	27.44	2,976			10.90	176.77	Rain and snow June 1 and 2.
3	Beaver Creek	4.20	4.25	59	35	16	753	47.0	27.12	27.03	3,354	46 52 35.2		25.00	201.77	
4	Beaver Creek	4.15	2.15	73	46	17	1,095	63.25	26.82	26.84	3,615			18.00	219.77	Clouds.
5	Near Cabin Creek	4.20	2.30	78	50	16	992	62.0	26.78	26.66	3,737			20.50	240.27	Clouds.
6	O'Fallon's Creek	4.05	4.20	77	58	20	1,340	67.0	26.89	26.91	3,552			22.30	262.57	Clouds.
7, 8, 9, 10	Powder River	4.20	7.35	64	58	27	1,620	60.0	27.23	27.40	3,173	46 30 02.2		31.75	294.32	Rain June 9 and 10.
11	Yellowstone River	4.25	6.20	68	53	19	1,177	62.0	27.74	27.68	2,708			24.10	318.42	Rain and hail.
24	Tullock's Fork	4.30 p.m.	7.00											4.20	322.62	
25	Big Horn River	5.00	7.00											23.58	346.20	Rain.
26	Little Big Horn River	4.00	6.00											29.23	375.43	
27	Little Big Horn River	6.00	9.00 a.m.											8.76	384.19	
28	Little Big Horn River	7.00 p.m.	12.00 p.m.											4.65	388.84	
29	Mouth of Little Big Horn River.	6.00 p.m.	2.00 a.m.											14.93	403.77	
Aug. 8	Rosebud Creek	4.45	2.15	106	73	7	603	86.1						9.40	413.17	Rain.
9	Rosebud Creek	4.45	5.10	75	50	12	768	64.0	27.05	27.07	3,376			11.00	424.17	Clouds.
10	Rosebud Creek	4.55	5.00	73	43	14	842	60.1	26.75	26.77	3,714			16.00	440.17	Clouds.
11	Tongue River	6.00	2.00											13.45	453.62	Rain.
12	Tongue River	6.00	2.30											13.08	466.70	Rain.
13	Tongue River	7.00	4.30											24.06	490.76	Rain.
14	Pumpkin Creek	6.00	3.00											15.75	506.51	Rain.
15	Powder River	6.00	4.00											20.28	526.79	Rain.

Summary table of daily instrumental observations, with deduced altitudes, latitudes, and longitudes, distances traveled, &c.—Continued.

Date.	Location.	Start.	Arrive.	Thermometer.					Barometer.		Elevation.	Latitude.	Longitude.	Day's march.	Total distance.	Weather.
				Maximum.	Minimum.	Number.	Total.	Mean.	Evening.	Morning.						
		A. M.	*P. M.*	°	°			°	*Inches.*	*Inches.*	*Feet.*	° ′ ″	° ′ ″	*Miles*	*Miles.*	
16	Powder River	6.00	3.00	......	......	......	......	......	......	......	......	......	......	19.68	546.47	
17	Yellowstone River	6.00	2.00	......	......	......	......	......	......	......	......	......	......	23.40	569.87	
18	Yellowstone River	6.00 p. m.	6.30	......	......	......	......	......	......	......	......	......	......	1.17	571.04	
25	Near Powder River	......	......	74	50	12	761	63.7	27.52	27.41	2,870	......	......	17.10	588.14	
26	Yellowstone River	......	......	75	55	14	934	66.7	......	27.64	2,793	......	......	22.30	610.44	
27	Dry Creek	......	......	86	53	3	198	66.0	......	......	......	......	......	6.22	616.66	
28	Fork of Bad Route Creek	......	......	98	61	9	713	79.2	26.85	26.85	3,583	......	......	20.95	637.61	
29	Clear Creek	......	......	78	54	8	491	61.4	26.86	26.86	3,576	......	......	17.72	655.33	
30	Deer Creek	......	......	77	56	6	391	65.1	27.64	27.64	2,795	......	......	17.69	673.02	
31	Yellowstone River	......	......	60	56	4	234	58.5	27.69	......	2,746	......	......	14.50	687.52	

JOURNAL OF THE MARCHES MADE BY THE FORCES UNDER COLONEL JOHN GIBBON, COMMANDING THE EXPEDITION DOWN THE YELLOWSTONE, BETWEEN THE 1ST DAY OF APRIL AND THE 29TH DAY OF SEPTEMBER, 1876, BY LIEUTENANT E. J. M'CLERNAND, SECOND CAVALRY, ACTING ENGINEER OFFICER.

April 1.—At 9 o'clock the four companies (F, G, H, and L, Second Cavalry) left Fort Ellis, Mont. They are preceded several days by six companies of the Seventh Infantry, which are already some distance down the Yellowstone, as is also the main supply-train. The object of this movement of the troops is a campaign against the hostile bands of Sioux, known to hunt and camp along the Lower Yellowstone and its tributaries. Stealing parties from these tribes raid the settlements in this vicinity every summer, killing defenseless persons who are so unfortunate as to fall in with them, and generally succeeding in running off a number of horses and mules. Owing to the melting snows, the roads are in a frightful condition, and so great is the difficulty in getting our train along that, although we work until after sunset, we only succeed in making seven miles. Our camp is on a little stream, a short distance above where it joins Middle Creek. The ground is saturated by melting snow, patches of which still exist. To-day's march has brought us in the midst of the hills forming the little divide between the headwaters of the East Gallatin and the Yellowstone Rivers. These hills, besides being picturesque, are exceedingly fertile, growing in places luxuriant bunch-grass, in others dense pine forests. The formation of the divide is usually sandstone, with the strata upturned at a large angle. In this divide, farther to the south, coal of a very fair quality has been found, and not far from this limestone. From the summit of a hill just back of camp one procures a fine view of the beautiful Gallatin Valley, with its rolling foot-hills and girdle of snow-capped peaks.

2d.—Continue our march in the direction of the Yellowstone. A short distance from camp we reach and cross Middle Creek, a clear stream running in a small but pretty valley, between high and gently-sloping hills, covered with fine grass. From here the road ascends a high hill, and soon reaches a point where the divide falls precipitously toward the Yellowstone. Passing from here down a steep hill, we reach, at its foot, Billman's Creek, 10 miles from Fort Ellis. A short distance on, the condition of the roads again compelled us to go into camp, after having marched only a few miles.

3d.—To-day we find the roads greatly improved, due to the fact that the snow never lies so long on this, the eastern side of the divide, as it does on the west, being carried away and evaporated by the high winds which prevail along the valley of the Yellowstone. We follow Billman's Creek through a natural pass between two high and almost parallel ridges, down the sides of which course innumerable little streams; those from the north crossing our road at short intervals on their way to Billman's Creek. In this pass and along the hill-sides the bunch-grass grows with the most lavish luxuriance. Twenty-one miles from Fort Ellis, Fleshman's Creek, a clear, cold stream, flowing from the northwest, is reached. Crossing this and proceeding on a short distance, we pass down the left bank of that river to "Benson's Landing," the head of Mackinaw-boat navigation. This valley is quite extensive, but being covered with loose gravel mixing with the soil, it is not very fertile, while the high winds which so frequently blow down the river make it an unpleasant place to reside. About three miles from Benson's, Shields' River joins the Yellowstone. It is distant from Fort Ellis 29.46 miles, and is a bold, rapid stream, flowing over small granite bowlders, and, rising on the northwest side of Crazy Mountain, it runs through an extensive and fertile section of country, which for some years past has furnished pasture for large herds of cattle. During the afternoon a wet and windy snow-storm came up and continued into the night.

4th.—We remain in camp to-day, awaiting the arrival of several wagons still detained by the heavy roads near Middle Creek.

5th.—Leaving Shields' River, our road crosses a spur of Sheep Mountain, which mountain presents a vertical face of basaltic rock to the Yellowstone.

A march of 7 miles brings us to a bottom on the Yellowstone, opposite the Old Crow agency. This valley, several miles in length and more than a mile wide, is very fertile. Leaving this, the road turns to the left and crosses a range of high hills; on the summit of one of these gypsum of a fine quality lies in sight. From here one commands an extensive view of the surrounding country. Crazy Mountain, lying just back of Sheep Mountain, is detached from the main range, and standing alone it seems to serve as a rallying point for the clouds, great masses of which almost always hover around the tops of its lofty peaks. Thousands of springs trickle down its rugged sides and are the sources of numerous streams. The altitude of Crazy Mountain is about 10,000 feet. To the south, across the Yellowstone, lies a range of high and rugged lava peaks, usually called the Yellowstone Range, whose summits "stand out in bold relief against the sky." Forty-four and one-half miles from Ellis, we reach Hot Spring Creek, on the banks of which, a short distance above the road, are several large and very warm sulphur springs. Three and a quarter miles on, the road crosses Duck Creek, running clear and cold from Crazy Mountain, and 1½ miles farther reaches the Yellowstone. Crossing here at a

tolerably good ford, we go into camp on the river. The camp is in a fine and large valley covered with good grass. Along the river the cottonwood trees grow to a great size. Distance traveled during the day, 19.60 miles.

6th.—To-day about noon we reach and cross the Big Boulder, 62.83 miles from Fort Ellis. This is a large and rapid stream, rising in a very high range of granite mountains to the south. Near its mouth it flows over large bowlders, hence its name. Fifteen miles above its mouth it is formed by three forks, each of which is filled with fine trout. These forks run through pretty little valleys, which are favorite resorts for elk. The road, still continuing down the valley of the Yellowstone, reaches, 7½ miles from the Boulder, Little Deer Creek, now dry. From here to Big Deer Creek, about two miles, lies as fine a piece of bottom-land as can be found anywhere. Having marched 21 miles, we encamped on Big Deer Creek.

7th.—Soon after leaving camp, we pass by what is known as the Point of Rocks. This is a high and vertical wall, nearly half a mile in length, and showing plainly the marks left by the river in times past, when it was thirty feet above its present level. A little less than 8 miles from camp, we cross Bridger Creek; its source is in an exceedingly broken country, but near its mouth it flows through a pretty little valley thickly wooded. Soon after crossing the last-named stream, we reach a point where the valley opens out finely, possessing rich black soil, and growing heavy grass. The Yellowstone is bordered by a fine growth of large cottonwood trees, and the foot-hills to the south are covered with pine timber. The country to the north, across the river, is very broken. After marching 20 miles, we encamped on the Yellowstone.

8th.—Moving down the valley 2 miles, the river is forded, to avoid some steep and broken bluffs which it washes on the south bank. This is one of the best crossings on the Yellowstone. Passing along the north bank a few miles, through a drenching rain, we reach the infantry camp, situated on the Yellowstone, 96.79 miles from Ellis. This command arrived here on the 6th, and has succeeded in catching a great number of fine trout. The cavalry are not slow in following their example and supplying themselves liberally with this delicious food.

9th.—Both commands move out about the same time, marching down the valley. Upon arriving at Countryman's Ranch, the train and the cavalry are crossed to the south side, while the infantry continue along the north bank over a range of rough hills. Something less than two miles from Countryman's Ranch lies the Stillwater River; it is a fine large mountain stream, flowing over large bowlders, and filled with trout. Along its banks grow large pines, in a bottom varying in width from one-half a mile to a mile. After passing over two small bottoms on the Yellowstone, separated by a high hill, it again becomes imperative to ford the river. The bed is here composed of large rocks, rendering the fording difficult and even dangerous. Soon after crossing we go into camp, in a pretty spot at the head of one of the largest valleys on the Yellowstone.

10th.—The command remains in camp while the train is sent to the Crow agency, situated on Rosebud Creek, a tributary of the Stillwater. It is 20 miles from camp. The train is to bring down supplies that have been left there. During the evening a furious snow-storm prevails, and at the agency it falls to a depth of 18 inches.

11th.—Most of the train arrives late in the evening. It is but little exaggeration to say the command is living upon fine trout caught in the Yellowstone.

12th.—The day is spent in loading the train for a forward movement.

13th.—Captain Logan, Seventh Infantry, is left with his company to guard such supplies as cannot be carried. The other companies move out as one command, and begin in earnest the campaign at 7 a. m. After marching two hours the range of mountains back of the Old Crow agency come in sight. They are covered with snow and present a grand appearance. We are traveling through a large valley of considerable fertility, and varying in width from 1 to 2 miles. The south side of this bottom is washed by the Yellowstone, while on the north it is hemmed in by steep sandstone bluffs 100 feet high, and rising gradually from the top to the little divide between here and the Musselshell River. On the south side of the Yellowstone the bluffs present a precipitous front, but a little way back break into rolling hills covered with fine grass. The roads are heavy on account of the recent snow, and the train moves slowly. At 3 p. m., having made 11.25 miles, we go into camp on the Yellowstone.

14th.—Breaking camp at 7 a. m., we continue to march through the same valley passed along yesterday. The width increases to 6 miles, but in other respects there is little change. In places the soil is slightly alkaline, and the last snow has made it quite soft. We encamp on the Yellowstone at 3.30 p. m. Distance traveled during the day, 14.12 miles. The bluffs across the river are growing darker, presenting a lignite appearance. A short distance above camp, Clark's Fork joins the Yellowstone, coming from the granite mountains to the southwest; it is rising and the water is of a light brown color, and in quantity seems to be about half as much as the Yellowstone. Along the banks of both grow cottonwood, and at their confluence there is quite a forest. For more than a mile above their junction these two streams run almost parallel; the bea-

ing up Clark's Fork being south 33° west, and up the Yellowstone southwest. A high wind continues to blow all night.

15th.—Starting at 6.45 a. m., we reach 2¼ miles from camp, Cañon Creek, which is now dry; it has its source near what are known as the Lakes. These are the remains of what have formerly been large lakes, near the summit of the divide between here and the Musselshell, and which now are important water-holes to any one traveling along that divide. A little way and we pass through some large sage-brush, about the first seen. To the north the bluffs present a vertical face, and running nearly 9 miles along the valley, look like a wall built by man to serve as a huge fortification; ten and a half miles from camp this wall reaches the Yellowstone, and there makes a sharp angle with the bluffs running along the river. In this angle is a break, affording an opportunity to ascend the plateau. From this elevated prairie the Red Buttes, sometimes called Bull Mountain, can be seen lying 12° east of north. Passing along this table-land about 6 miles, we reach a valley on the Yellowstone and go into camp, just below "Baker's battle-ground," at 6 p. m. Distance traveled during the day, 17.35 miles.

16th.—Break camp at 9.35 a. m.; about 4 miles below camp we cross the Yellowstone, to take advantage of a large valley on the south side; the ford proves to be deep and swift. Lieutenant Schofield, Second Cavalry, missing the ford a few feet, comes very nearly being drowned. On the south side a continuation of the sandstone bluffs seen since leaving Captain Logan's camp still faces the river; but, stopping abruptly here, and receding from the stream, gives place to an extensive valley. A little way below, on the north side, is the commencement of a long range of broken and barren hills. A distance of nearly 7 miles from camp brings us to Pryor's Creek. This creek, rising in a large mountain of the same name, lying to the south, is swollen by the melting snows, and runs a stream of muddy water 10 yards in width and over 2 feet deep. After crossing, we follow it down to its mouth and camp on the Yellowstone, at 3.30 p. m., having marched 7.07 miles. The river-water is becoming very muddy, due probably to the rise in Clark's Fork. Since passing, the mouth of that stream, few if any trout have been caught. A band of elk were seen to-day and several killed.

17th.—Starting at 8 a. m., we march down the valley, intending to camp near Pompey's Pillar. After marching three miles, a halt was made to wait for the train.

The surrounding country is very beautiful. The valley itself is one of the finest to be seen on the Yellowstone, varying in width from 1 to 6 miles, and averaging about 2½; it extends for miles along the river, and contains perhaps 70,000 acres of arable land, all of which lies favorable for irrigation from either Pryor's Creek or the Yellowstone. It grows fine grass, and in places large sage-brush. The scenery is varied and extensive. To the southwest can be seen the lofty Yellowstone Range, covered with snow; to the north and northwest the bluff country toward the Musselshell stretches away as a vast plateau. To the south and east the gently-rolling hills are lost in the far distance in the granite ranges of the Big Horn and Pryor's Mountain. The valley descends in gentle declivities from the foot-hills, and bears north 40° east. Along the Yellowstone cottonwood timber grows with great luxuriance. To convince one that this valley has a bright future, it is only necessary to remember that the river flowing along its entire front is navigable two months in the year for Upper Missouri River steamboats. Eight and fifteen-hundredths miles from camp, Cachewood or Arrow Creek is reached, and at the crossing is dry, but half a mile above sufficient water, probably snow-water, is found for the animals. The day is very warm and threatens rain; toward evening we gradually approach the river, and reach it just below Pompey's Pillar. A little way below this, camp is placed, about sunset, inside of a semicircle of cottonwood trees; distance marched, 15.80 miles. Accompanied by Dr. Paulding, I rode to the foot of the pillar, and fastening our horses we easily ascended along its northeast side; indeed here the ascent is so good that one of the scouts reached the summit mounted on a little mule. This rock, named in 1806 by Captain Clark, lies on the south bank of the river, a few yards from the water. It is 160 feet high and 200 in diameter. The soil on the top varies in depth from 1 to 4 feet. The rock is a gritty sandstone. Great blocks that have broken loose lie scattered around its base, and on the east side a huge rock, nearly as high as the pillar, and 5 or 6 yards in diameter, appears ready to fall. On all sides except the east the rock has vertical faces, and is cylindrical in shape. Having reached the summit the view is very grand, especially to the east, south, and west. On the north bank of the river the view is somewhat limited by the bold, rugged sandstone bluffs, about the same height as the pillar, and to which it has undoubtedly been formerly attached. A few miles back these bluffs break into a rolling country, studded with a stubby growth of pine, and presenting a most barren and uninviting appearance. These hills, extending to the Musselshell River, and running along the Yellowstone 40 miles, constitute one of its poorest sections. In a direction north 55° west is seen a range of high, red-looking hills, the Red Buttes. South 64° west lie the snowy peaks on the head of the Stillwater, 60 miles away. About 10 miles down the river, on each side, lies a range of high, rough hills, running almost north and south, and covered on this side with a growth of small pines. The valley is seen merging itself into the foot-hills to the

south, and these in their turn rise to Pryor's Mountain. The storm that threatened us to-day has cleared away, and the clear atmosphere enables one to see many distant objects of interest, too numerous to mention.

18th.—We remained in camp awaiting the return of several scouts sent last night to the mouth of the Little Big Horn River to prospect for a Sioux village. A high wind has been blowing all the afternoon, and continues now late in the evening, almost burying us in the great clouds of sand it sends before it. The scouts return, having failed to discover any signs of hostile Indians.

19th.—Starting at 7.30 a. m., a few minute's march brings us to Fly Creek, 1¼ miles; the banks are steep and generally soft; the water stands in holes. The valley now narrows and is badly cut up by ravines, but a mile on again opens out nicely; the wind still continues to blow and drive clouds of sand along the river. Ten and a half miles from camp a range of bluffs abruptly terminate the valley, rendering it necessary to cross the river with the train. Leaving the valley we have been traveling in for thirty miles, and fording the river where it is 580 feet wide and 3¼ deep, we pass along the north bank 2¼ miles and then return to the south side. The ford is 632 feet wide and 3 feet deep; the valley we now enter is narrow and by no means pretty, although the soil is fertile. The rolling foot-hills seen above give place here to steep bluffs of sandstone, scantily covered with scrubby pine timber, and besides being poorly watered produce but little grass. At 4.45 p. m. we encamped on the Yellowstone in a semicircle of large cottonwood trees. Distance marched during the day 18.60 miles.

20th.—Starting at 7.40 a. m., we continue to pass along the river. The bottom is mostly covered with sage-brush, and for the first 7 miles grows poor grass; after that it improves. Nine and eight-hundredths miles from camp a high range of hills lying this side of the Big Horn River presents a steep face to the valley we are in, forcing us to cross the river. Some difficulty is experienced in finding a ford, and when one is selected the animals can scarcely cross without swimming; the river is evidently rising. After crossing, our road passes for 1¼ miles through a sage-brush bottom, and then gains a high plateau. Moving along this elevated ground we pass the mouth of the Big Horn River, and obtain a view of its valley for a long distance. Four miles over this plateau brings us to the head of the Fort Pease Valley; here the grass is luxuriant, and the river-bank is grown up with large cottonwoods and heavy brush; many of the trees are 2½ or 3 feet in diameter, and show plainly by the short distance of the limbs from the ground that this end of the valley has filled up several feet in recent years. This is explained by the fact that two large ravines in the hills to the north do not continue their course to the river, and thus after a hard rain the loose material brought from the hills is scattered promiscuously over the bottom. Having marched 17.17 miles, we encamped in a grassy spot at 4.45 p. m.

21st.—This morning instructions via Fort Ellis are received, ordering us into camp at Fort Pease, there to await further orders. The same mail brings information that the troops from the other directions will not be able to take the field for some time. We move on to Fort Pease, 2.02 miles, and 215.32 miles from Fort Ellis. The command is put in camp immediately outside of the fort.

22d.—The day is passed in policing Fort Pease, something it stands in great need of. The fort, built of rough cottonwood logs, is about 75 feet square, with a bastion on the northeast and southwest corners, erected in June, 1875, by a party of citizens. It was intended as a headquarters for "Wolfers," but the Indians made life there a burden, and it was abandoned in February. It is situated in a valley about 10 miles long, and varying in width from one-half to two miles. The soil is fertile and grass good. Steep bluffs hem it in on the north, and those to the south across the river are very precipitous and extremely broken.

23d—Remain in camp. Captain Freeman, Seventh Infantry, starts with his company and the train, to bring down supplies left at Captain Logan's camp. To avoid trouble in crossing the river, he is ordered to keep the north bank.

24th.—H and F Companies, Second Cavalry, under command of Captain Ball, receive orders for a seven days' scout, via the Big Horn, Fort Smith, and Tullock's Fork. I am ordered to report to Captain Ball. Starting about noon, the two companies march up the river to a point just above the mouth of the Big Horn, and cross at a good ford 5¼ miles from Fort Pease. This distance is estimated from the time of march, as, indeed, all distances on this scout must be. Remaining in camp until 6 p. m., to avoid being seen, and then starting in a direction south 35° west, we soon ascend the bluffs, and reach a high ridge or "backbone" The Big Horn River and its valley is to our left, and just beyond it a picturesque but broken and worthless country. Directly ahead, about five miles away, lies a low wooded bluff, and in the far distance can be seen the Big Horn Mountains, which running east and west terminate the landscape like a huge white wall. For 11 miles our course is south 45° west, and passes through a very broken country; in several places the water-channels draining into the Yellowstone and Big Horn Rivers almost join on the summit of the "divide." Here and there the ridge is sparsely covered with small pines. Frequently it is necessary to wind around and around to cross a deep ravine or turn a precipice. Our Indian guide, how-

ever, is equal to the emergency, and wins the admiration of all by the masterly manner in which he guides us through this broken country in the darkness of night. After 11 miles our course is southeast through barren hills. At 11.30 p. m. we encamp on a tortuous little stream, with water standing in pools. The Indians call this Wood Creek. The grass is poor, and consequently the horses get but little to eat. Distance from the Yellowstone, 16 miles; from Fort Pease, 21½ miles.

25th.—Starting at 9.15 a. m., one of our scouts informed us we could travel during the morning and be well concealed; in this he soon proved to be mistaken. An hour's march through high, rough hills, in a southeasterly direction, brings us to the valley of the Big Horn; this stretches away for miles, a little west of south. It proves to be large and fertile, gaining a width in places of 4 miles. It is poorly supplied with creeks, but could be irrigated from the river. A portion of it grows sage-bush and cactus. Buffalo and antelope are seen in the valley and on the foot-hills. At 1.20 p. m. a halt is made on the Big Horn, and the animals turned out to graze. Distance marched during the morning 16 miles; distance from fort 37½ miles. While here a band of elk quietly walk in among the horses, and graze with them for several minutes. At 6.40 p. m. we continue our march up the valley, and in 35 minutes reach the mouth of the Little Big Horn River, coming in from the southeast on the opposite side through a green and pretty bottom. There is a great abundance of cottonwood timber on each stream, but especially on the Big Horn. The pine on the surrounding sandstone bluffs is of a poor quality. The valley of the Big Horn at this point is broad and fertile. After marching 4½ hours (14½ miles) the valley is terminated by high bluffs; it is too dark to see if there is a bottom on the opposite side, but as a general rule in this country, the bluffs lie opposite valleys. A mile and a half farther on, at 11.30 p. m., we turn to the left and camp on the river in a small cove formed by the hills. Distance marched during the day 32 miles; distance from Fort Pease 53½.

26th.—Six a. m. finds all ready to move. Crossing the river just above camp, where the water is 2½ feet deep, we march a mile and a half, and halt on the river-bank in a fine valley; the grass is good, and we determine to remain several hours to permit our animals to feed. The valley, which is here more than a mile in width, can be seen extending in a direction 7° west of south, to the very foot of the Big Horn Mountains, 25 miles or more away. In it the grass seems to be everywhere good. The river runs about one-half as much water as the Yellowstone, and on the opposite side washes steep sandstone about 100 feet high. While resting here buffalo can be seen feeding in the valley and foot-hills in all directions, in little bands of from ten to thirty. Some of them coming within a few yards of camp enables us to procure meat with little trouble. At 1.30 p. m. our march is continued; the valley increases in width to between four and five miles. At a distance of six miles from camp we arrive opposite the mouth of Beauvais Creek, running in a direction 4° south of east, through a pretty and well-timbered bottom. Twenty minutes later Rotten Grass Creek, coming from the southeast, is crossed, running in a ravine 12 feet deep, with steep banks and a muddy bottom. The stream is 10 feet wide and a foot and a half deep. On its south bank the grass is heavy enough to make hay. Fifteen miles from our last resting-place the valley narrows to 400 or 500 yards, but a short distance on again becomes more than a mile wide. At 6.05 p. m. we reach and cross Soap Creek near its mouth. Like Rotten Grass its banks are steep, but the bottom is much harder; the water is clear and cold. At 6.15 p. m. we go into camp on the Big Horn, having marched during the day 20½ miles. Distance from Pease 74 miles. As the grass is good, Captain Ball decides to remain here all night and next day, to recruit our horses and pack-mules, many of them being very weak. All day we have been traveling through a magnificent valley, averaging about 2½ miles wide, with a rich black loam soil, producing luxuriant grass, which is bright and green. The foot-hills, too, grow more fertile. The sandstone formation around Pease, here gives place to granite, always the herald of better and more pleutiful wood, water, and grass. Altogether it is the finest piece of tillable land I have seen in Montana; not a stone, cactus or sage-brush is to be found in the valley, and water is everywhere abundant.

27th.—We move in the afternoon at 5.15 through the "Hayfields" of old Fort C. F. Smith, in a direction south 39° west, and after marching 3 miles, reach that place, abandoned in 1868. Most of the walls are still standing, built of adobes on stone foundations. The roofs, however, are all destroyed; the flag-staff lies across the parade-ground, and from the manner in which it is cut, we supposed it was felled by Indians. The cemetery is least injured of all, and the monument erected to the late Lieutenant Sternberg and fifteen soldiers and citizens is but little defaced, the corners having been chipped away in several places with a hatchet. This monument, standing alone in the wilderness and erected by sorrowing friends, was the last token of love for those who slept here beneath the sod, waiting long, and perhaps in vain, for the country they served to avenge their death. It is built of limestone, which I suppose was found some place in the mountains lying 2 or 3 miles to the south. These mountains are covered with fine large pines, which could be easily floated down the river, if needed for building in either of the two valleys of the Big Horn. The Big Horn Cañon, looking very

deep and of a red color, is about 3 miles above the fort. The location of this post is inferior, in every respect, to many places down the valley. The weather is cool and threatens rain. Near the fort we see the camp made a few days ago by a large party of citizens on their way to the Black Hills. Leaving Smith at 5.05 p. m., and intending to travel during the night in a general direction southeast, we move along the old Phil. Kearney road to where it crosses the head of Soap Creek, and a little way on ascend what was known in the days of Fort Smith as the Big Hill. Soon after reaching the top of this, we leave the road to our right, and cross several very miry streams, probably branches of Soap Creek. The course selected takes us through beautiful high rolling hills, covered with fine grass. At midnight a halt is made on Rotten Grass Creek, where the water and grass are good. Small timber grows along the banks of the stream, which flows through a pretty though narrow bottom, apparently extending all the way to the valley of the Big Horn. Distance travelled since leaving last camp, 18 miles. Distance from Fort Pease, 92 miles.

28th.—Saddling up and starting at 9.25 a. m., we move in a direction 60° east of north, and at 10.10 a. m. reach a small tributary of Rotten Grass, with good wood, but poor and little water. We pass up this creek a short distance, and then over high rolling hills thickly carpeted with grass. Large game trails cross the country in all directions, but so far this morning we have only seen a band of antelope. At 11 o'clock we are at the top of a high divide, and turning north 71° east pass down a little creek, along which are seen a number of white-tail deer. Buffalo are in sight again. At noon having marched 7¼ miles, a fine stream is reached and a halt made. Here we find hard-wood (ash) growing, something I have never before seen in Montana. As numerous little creeks join this one, we name it "Many Stream Creek." The valley is about a half a mile wide, and runs a little west of north. The belt of country we are now traveling in is as fine a grazing district as can be found anywhere, combining hills and valleys, with everywhere a perfect mass of the most nutritious grasses. Numerous streams, fed by the melting snows of the Big Horn Mountains, furnish clear and pure water at short intervals. Besides, the country is alive with game; buffalo, elk, deer, and antelope are seen in great numbers. It is a hunter's paradise. At 2 p. m. we are again in the saddle; traveling north 39° east, brings us at 3.25 p. m. to a small creek running north 45° east. This we follow down three miles to where it joins another running north 71° east; crossing the latter and passing down its north bank four miles, we arrive opposite the mouth of a creek entering from the south; the two combined run a nice stream. The Indians call this Long Creek, but on the map it is named Grass Lodge. Along the banks there are ash and cottonwood timber growing in a valley three-quarters of a mile broad. At 6 p. m. we reach a large stream issuing from a little bottom almost hidden by the hills. This is the Little Big Horn River. Turning to the left we move one mile down the left bank, and unsaddle in a pleasant and strong camp. On the opposite side of the river are high and broken sandstone bluffs, but on this side is a beautiful and extensive valley more than a mile wide. In the soil, like that in the upper valley of the Big Horn, not a pebble is found; it has a gentle slope to the river, and is everywhere covered with good grass. The river-water is clear and cold, a fact that renders it very agreeable, as the day has been warm. Ash timber grows along the banks in great abundance. Distance marched during the day, 21¼ miles; since leaving Fort Pease, 113¼.

29th.—This morning we start at 8.45, and continue our march down the left bank, in a direction about 5° west of north. On the right bank the high bluffs are badly cut up with deep ravines. A few miles from camp we see where a large Sioux village was last summer. The valley increases in width, and, if possible, in beauty. At 11.25 we reach a point where the river washes the hills near Custer's battle-ground, on its west, but a short way on again turns to the right, and leaves a second beautiful and extensive valley on its left. Near this point we cross the river twice; it is about 15 yards wide and 18 inches deep, with a good but not a swift current. At 12.45 we halt to noon. Distance traveled this morning, 12 miles. Wolf Mountains, lying to the east, have been in sight nearly all morning, and directly up the river can be seen the mountains of the Big Horn. The bearing down the valley is north 3° west. We move in the afternoon at 2.30 6 miles down the river; then turning to the right and crossing it we leave the Little Big Horn and its pretty valley. Our course is northeast. Passing into the hills, we are soon in the midst of a very broken country. After 3 miles our course changes 15° more east, and at a distance of 5 miles from the Little Big Horn we reach one of the tributaries of Tullock's Fork, and are disappointed in finding it dry. Turning to the left, we follow down this dry gully, intending to halt as soon as we find water. A little way on we see a small buffalo-herd, and kill five of them. 8.45 p. m. brings us to a miserable little creek, coming in on the right, in which the buffalo have been recently wallowing, and near which they have eaten off all the grass. Making a virtue of necessity, we go into camp, having marched 15 miles since noon, and 27 miles during the day; since leaving Fort Pease, 140¼.

30th.—Getting off at 5.15 a. m., we march down the left bank of Tullock's Fork, bearing north 6° west. The sandstone formation has once more replaced the granite,

and the country is poorer. On each side are rough, barren, and poorly-watered hills, many of them looking but little better than the Missouri River bad lands. At 8 a. m., having marched 9 miles and finding good grass, we halt and turn the animals out to graze. Ash grows in the bottom, which is a half a mile wide. The water, standing in pools, is cold and tolerably good, although not clear. Moving again at half past 12, our route lies down the creek, bearing north 14° west, but 3 miles on changes almost due north. Small pine timber begins to appear on the hills, and on the sandstone spurs running down from Little Wolf Mountains. Buffalo have been around us all day, and quite a number of deer are seen. At 4 p. m., after marching 11 miles, we halt for the night. Distance marched during the day, 20 miles; since leaving Fort Pease, 160½. We have now nearly completed our scout, and no fresh Indian signs have been discovered. Many of our horses and mules are very weak, several having already been abandoned.

May 1st.—We start this morning at 7.15, and continue down the creek, bearing north 16° west until 8.30 a. m., when it changes north 23° west, and a half an hour later (nearly 2 miles) north 28° west. As the creek is very crooked, we cross it often. The bottom grows good grass, large cottonwoods and ash; it is bordered on each side with broken bluffs, covered with scattering pine timber. Deep ravines, looking as if in wet seasons they carry great quantities of water, put in freqnently on either side. After marching 12 miles we reach the mouth of Tullock's Fork, emptying into the Big Horn about a mile above the junction of the latter stream with the Yellowstone. Passing through a small valley on these two rivers, we cross the Yellowstone 2½ miles below the mouth of the Big Horn. The ford is 4 feet deep, and as the current is very swift, it is crossed with great difficulty. Two miles farther on we rejoin the command at Fort Pease, at 3 p. m. Distance marched on the scout, 178 miles. The command remains in camp here until the 10th.

On the night of the 2d and 3d the Crow scouts, who, contrary to orders, failed to tie up their ponies, had them stolen by a small party of Sioux from down the river. On the 7th a Mackinaw boat arrives from "Benson's," three days out. On the 8th Captain Freeman and Captain Logan reach us with supplies we left behind.

10th.—To-day we commence to move down the river, intending to travel slowly until General Terry is heard from. Breaking camp at 8.30 a. m., the command moves down the valley; three miles on there is a bad ravine running from the hills to the river. It is from 15 to 20 feet deep and 25 wide, with a muddy bottom and vertical sides of soft earth; two miles farther there is another. It is evident that they serve as important water-channels for the hills to the north. Although dry now, the train is greatly delayed in crossing them. The valley between them is broad and fertile, and the cottonwood timber along the river very dense. The steep sandstone bluffs to the north are becoming of easier ascent. On the opposite side of the Yellowstone the broken hills, covered with scrubby pine, begin to recede from the river. These hills, although by no means fertile, are picturesque. After traveling 7 miles our road turns to the left and ascends the bluffs, and, having reached the top, we find ourselves on an extensive plateau. Due east can be seen a sharp-pointed butte, a very prominent landmark, to which I give the name Cayote Butte. The guide, Mich. Bonyer, informs me it stands on the east side of the Great Porcupine, just where this stream enters the Yellowstone Valley. To the north, in the direction of the Musselshell and the Dry Fork of the Missouri, the country is sterile and barren. The course of the Yellowstone, seen for a great distance, is a little north of east. On its south bank lies a large valley. There is much gravel in the soil along the plateau, and the grass is poor. A deep ravine runs through it, about 12 miles from Fort Pease, in which there is water standing in pools. It soon begins to rain in torrents, but, thanks to the gravelly soil, this does not make the ground very soft. About 6 p. m. we turn to the right, and, passing down a ravine, reach the Yellowstone, on which we go into camp, among large cottonwoods, at 7.30 p. m.; distance, 16¾ miles. The general bearing of to-day's march is north 60° east. Captain Clifford, who, with his company of the Seventh Infantry, came down the river in three small boats found at Fort Pease, arrives safely.

11th.—Remain in camp.

12th.—Starting at 7.20 a. m., a few minutes march brings us to "Froze-to-Death Creek," so named by the Crows, because nine of their tribe once froze to death near it. There is but little water in it, and that is poor; it has a narrow bottom, in which there is some timber. On each side are "bad lands," containing many fossils, mostly mussels. Just beyond this creek the valley increases in width, and finally becomes nearly 3 miles wide; it grows large sage brush, but the grass is generally poor. The hills to the north look sterile and broken. Seven and a quarter miles from camp it becomes necessary to take to the hills. Crossing a dry creek along the banks of which are a great many fossiliferous sandstone rocks, and passing through some barren hills, we gain a high and large plateau, 11 miles from camp. From here one obtains an extensive view. In every direction can be seen an elevated country, broken here and there by cragged sandstone bluffs and buttes; occasionally by a little bottom on the Yellowstone, and sometimes by the river itself. In this numerous islands, heavily wooded, begin to appear. At

5.30 p. m. we encamp on the Yellowstone, in a pretty spot surrounded by cottonwood groves. Distance marched during the day, 18.90 miles. On a bar in the river, which, by the way, is rising, are the carcasses of eight buffaloes; doubtless they broke through the ice last winter during the passage of a large herd.

13*th*.—Remain in camp; a scouting party is sent to the Rosebud, and returns without seeing any signs of Indians.

14*th*.—Breaking camp at 7.45 a. m., our route lies through a little bottom bordered on the north by the ceaseless bluffs of sandstone in horizontal layers; 3.7 miles from camp we reach and cross the Great Porcupine, in which there is a little water, tolerably good. Its banks are generally steep and its bottom soft. At this point the valley is broad and fertile, and grows dense timber along the river. Nine miles from camp our guide discovers a fine spring, which we dig out and name after him, (Bonyer.) Here the bluffs circling around run down to the river, a fact that causes us to pass once more into the hills. Traveling along the bed of a dry creek, we reach after much winding the top, but a half a mile on pass down another ravine, so narrow in places that it scarcely permits a wagon to pass. From the cut banks seen along here, it is evident there have been several drift periods, (of gravel,) covering the country from 2 to 5 feet deep. At the mouth of this creek, 12.10 miles from camp, a fine band of elk approach within a few feet of us. Turning to the left and following along the river, we pass through a sage-brush bottom, and go into camp on the Yellowstone at 4.45 p. m., nearly a mile above the Little Porcupine. Distance marched during the day, 16.97 miles. Our camp, situated in a bend of the river, is a good one. The valley, which is nearly two miles wide, is skirted on the north by sandstone bluffs, many of them having a flat top, which caused Lewis and Clarke to call the Little Porcupine "Table Creek." The sandstone formation exists everywhere in this section, and the layers are almost always horizontal. Most of the streams from the north run dry while passing through the arid hills. Two hours after going into camp a rain-storm completely floods the camp; this is followed by a severe hail-storm, which stampeded the herd.

15*th*.—Remained in camp. The Little Porcupine, swollen by yesterday's rain, runs a stream of very filthy water 30 feet wide and 18 inches deep. We remain in this camp until the 20th. On the 17th a movement is started against a Sioux village which has been discovered on Tongue River, but on account of being discovered before the crossing is completed, and the difficulty of making the horses swim the river, the movement is abandoned.

20*th*.—This afternoon some of the scouts report the Sioux crossing in large numbers at the mouth of the Rosebud Creek. Leaving a small party to guard the train, the rest of the command moves down the valley, crosses the Little Porcupine, then on through a large valley to a point opposite the Rosebud. The report about the crossing is now found to be a mistake. About a mile below the Little Porcupine is one of those deep ravines which one sees so often along this portion of the Yellowstone. The valley is about 3 miles wide, and, if irrigated, would produce fine crops. Across the river, which is skirted by heavy timber, in a direction south 17° east, are the Big Wolf Mountains, a bunch of low sandstone peaks; still farther to the east can be seen a line of broken hills lying this side of Tongue River. Having marched 8.66 miles, camp is made on the river between 2 and 3 miles below the mouth of the Rosebud. The command remains in this camp until the 5th day of June awaiting supplies and news from the troops that are to come up the river. Indians hover around from time to time, but scamper off upon the first signs of pursuit. During the first few days the weather is very warm; then it turns cold and snows, and again clears up and is pleasant. The river rises nearly 5 feet, and is 250 yards wide. The Indian village is supposed to have moved to the Rosebud some 15 or 20 miles above its mouth.

June 5th—This morning the movement down the river is continued. Breaking camp at 9 a. m., we march down the valley, and about 2¼ miles from camp cross a deep ravine which we have bridged. Farther on the soil is alkaline and soft. Having traveled 9 miles, we reach a point where the valley is terminated by a steep hill which cannot be turned. As it is too late in the day to attempt to cross it, we encamp on the river in a beautiful spot at 1.45 p. m. Several bears are seen, and one killed. The day has been exceedingly warm, but in the evening, as full moon rises, it is pleasant, and the camp extremely pretty.

6*th*.—Starting at 7.40 a. m., 20 minutes' march brings us to the foot of the "Steep Hill;" it is only 275 yards long, but is covered with loose gravel, and so steep that it takes us 3 hours to get the train up. Having reached the top, the rough and barren hills can be seen extending for miles to the north. Bearing to the left, we soon begin to descend along a small creek, in the banks of which lignite is cropping out between layers of sandstone; 5.69 miles from camp we again reach the Yellowstone and its valley. Passing through a sage-brush bottom, along heavy timber, and over deep ravines, we encamp on the Yellowstone, among large cottonwoods, at 4 p. m., having marched 10.54 miles. The evening is pleasant, but during the day there have been occasional showers.

7th.—We start this morning at 7.40 and continue our course along the river. The march is not a pleasant one, for the day is dark and cloudy, with a stiff and cold breeze blowing. The ground is literally covered with cactus, the largest I have ever seen, and through this the men and animals pick their way carefully, but not without pain. The valley is 13 or 14 miles in length, and over 4 in breadth, and, if irrigated from the river, would doubtless make fine farms. Seven and three-fourths miles from camp our road crosses a dry creek, just where it issues from the hills, and a short way on ascends the bluffs,gaining a magnificent plateau. The grass, unlike that on most of the table-lands we have passed over, is very fine. The soil is black, rich, and entirely free from pebbles; it can be seen stretching away for miles to the north, and finally runs itself out in a rough-looking divide. In the afternoon we pass the mouth of Tongue River, coming in on the opposite side, and flowing through a large and fertile valley, thickly timbered. Our elevated position enables us to see up it about 12 miles, when it turns to the southwest, after which it is hidden by the hills, looking rough and barren. To the east the very broken divide this side of Powder River is plainly in sight. Some difficulty is experienced in finding a place to get the train down to the river, but finally a little bottom about 3 miles below Tongue River is selected, and we go into camp at 7.10 p. m., after a march of 21¼ miles.

8th.—Last night the river rose 6 inches; the morning is cool and pleasant. Moving at 7.40 a. m., we pull up a long hill, and crossing over a narrow ridge descend into the valley of Sunday Creek, in which the water is a half a foot deep, but is not good. Distance, 2.89 miles. The bottom is from a half a mile to a mile in width, and grows good grass and some timber. Following down this creek nearly four miles, and then turning to the left, we cross over a low pass and reach a fine, large valley on the Yellowstone. The grass grows luxuriantly, and is heavy enough to cut for hay. At 3 p. m., having marched 10¼ miles, a halt is made for two hours and the animals turned out to graze. Buffalo Rapids are just below us; they are caused by a ledge of sandstone running across the river at an angle with the channel of about 60°, and by loose bowlders below this. At present there is plenty of water on them to permit the passage of any boat on the Upper Missouri. At 5 p. m., the march is resumed and continued until 8 p. m., when we encamp on the Yellowstone; near camp is one of those deep ravines so common in the valleys between here and Fort Pease. At this point another sandstone reef runs across the river; it is not, however, so bad as the one above. But little timber grows along the river in this valley, which in other respects is one of the finest on the Yellowstone. It is about 5 miles wide and 11 in length, and is everywhere covered with thick green grass. Distance marched during the day, 16.15 miles. Distance from Fort Ellis, 334.32 miles.

9th.—General Terry arrives this morning on the steamboat Far West, and returns down the river after a stay of less than two hours. General Custer is on Powder River, and is to move up, while we, taking the back trail, are to take a position opposite the mouth of Rosebud Creek. During the afternoon there is a heavy rain-storm, which continues into the night.

10th.—The rain continues until 8 a. m. The ravine mentioned as being just below camp, and which was dry yesterday, now runs a stream 12 feet deep and 15 wide; this explains the many deep cuts seen in the bottoms between here and Fort Pease. Rains falling in the bad lands back of these valleys penetrate the soil only about 6 or 8 inches, when a kind of paste is formed which turns water like a roof. The water descending through the narrow ravines among the hills strikes the valleys with great force and cuts deep channels for itself, the sides of which are as steep as the walls of a room. I have seen the rains pour down in torrents among these bad lands, and although one raises great masses of mud at each step, yet just beneath this, at the depth of six or eight inches, a fine dust, not unfrequently red like brick-dust, is scattered by the wind. The command returns from here to a point about four miles below the mouth of the Rosebud, the cavalry going first, preceding the infantry one day. The late rains have made the roads very soft, and in addition to this there is great difficulty in getting over Sunday Creek, and on the plateau beyond this creek, which on the 8th had scarcely any water, is now, the 11th, a river 50 yards wide and from 3 to 6 feet deep. The marches of the cavalry were estimated, those of the infantry were measured, and are as follows, viz:

On the 11th, 9.23 miles; on the 12th, 15.6; on the 13th, 13.16; on the 14th, 11.88; total, 49.87 miles.

We remain in camp here (4 miles below the Rosebud) until the 21st. Most of the time the weather is very warm. The river, already high, continues to rise. On the 17th the Crow scouts report a big dust on the Rosebud, and shortly afterward a number of horsemen on the opposite bank of the Yellowstone, 2¼ miles above. By means of signals, General Gibbon learns it is Colonel Reno with six companies of the Seventh Cavalry. The river is so broad that we have to use field-glasses to read the signals. They have been scouting on Powder and Tongue Rivers, and on Rosebud Creek. No Indians have been seen, but a large trail leading toward the little Big Horn has.

Colonel Reno returns down the river to-morrow to rejoin his regiment, supposed to be near Tongue River.

On the 21st, the *Far West*, with General Terry on board, arrives; orders are given us to proceed at once to Fort Pease. This movement has been in part anticipated, as we are all packed and ready to start. At 9.45 a. m. the march is commenced. While passing the mouth of the Rosebud a big dust is seen in the direction of Big Wolf Mountains, and soon General Custer's long line of cavalry comes into sight. Having marched 18.95 miles, we go into camp on the Yellowstone, at 7.45 p. m., in the lower end of the Great Porcupine Valley. The tents are scarcely pitched when a severe hail-storm sets in; the hail-stones, which are half as large as an egg nearly drive the horses frantic. At midnight Lieutenant Low reaches us with a battery of Gatling guns; he came from Fort Lincoln with General Custer. The country from here to Fort Pease having been already described, it is unnecessary to give the journal in full here. The cavalry and infantry march separately; the marches of the former are estimated, and those of the infantry measured. They are as follows, viz:

On the 22d, 20.73; on the 23d, 21.04; on the 24th, 3.76, (2¼ miles above Pease.) Total distance since leaving camp on the morning of the 21st, 64.48 miles.

June 24th.—The *Far West* arrives at 6 a. m. General Terry is aboard, and intends to accompany our column. One company of infantry is left to guard the train, the rest of the command begins crossing immediately. By 5.30 p. m. we are in camp on Tullock's Fork, near the mouth, and 4.02 miles from our camp of this morning. General Gibbon is so sick that he is obliged to remain on the boat, which is to run up the Big Horn, and meet us if possible at the mouth of the Little Big Horn. The plan of the campaign seems to be for us to move to the Little Big Horn, and thus get below the village supposed to be on that stream, while General Custer strikes them from above. Both commands have left their wagons, and are traveling with pack-animals.

25th.—Starting at 5.45 a. m., we move up Tullock's Fork 3.3 miles, when it is decided to turn to the right along a dry creek, and ascend the ridge between here and the Big Horn. Having reached the summit, it becomes absolutely necessary to follow it, although it is narrow and very crooked. The entire divide is composed of sandstone, usually in horizontal strata. Rough ravines, hundreds of feet deep, and filled with scrubby pine, run back almost to the summit from both the Big Horn and Tullock's Fork. The day is excessively warm, and the infantry toiling along over the broken country, suffer much for water, which cannot be found any place along the divide. After marching 21.35 miles, and passing down a hill where the Gatling guns have to be lowered by hand, the Big Horn is reached, enabling men and animals to quench their intense thirst. Halting here a few minutes we again take up the march, and climbing over a high hill reach a pretty bottom on the Big Horn. Here a halt is made among noble cottonwood trees. Distance marched during the day, 23.65 miles. On the opposite side of the river, the large valley mentioned in the journal of April 25th, begins to open out. At 4.30 p. m. the rain begins to fall heavily, but General Terry decides to push on with the cavalry and battery, desiring to get in the immediate vicinity of the Little Big Horn as soon as possible. The infantry being completely exhausted by the day's march, which has been a severe one, is to remain in camp, and follow in the morning. At 5.15 p. m., we are again in the saddle and continuing our march up the Big Horn. After leaving the little bottom, in which we have been resting, our course lies over rough hills and across deep ravines. Night comes on very dark, and the rain continues to fall heavily until 10.30 p. m. It is with difficulty that the parts of the command in rear can see to follow those in advance. The battery especially has great difficulty in keeping up. At midnight we halt on a ravine, where there is a little water standing in holes, and near which the grass is tolerably good. There is some wood here, but to prevent all risk of signaling our approach, no fires are lighted. Distance marched since leaving the infantry, 12.10 miles; during the day, 35.75.

26th.—Starting at 9.15 a. m., we go but a short way, when Lieutenant Bradley, in charge of the scouts, brings in word that two of our Crows who were sent with General Custer, are on the opposite side of the Big Horn, and say that General Custer was badly beaten yesterday and killed in a fight about 18 miles from here on the Little Big Horn, which river is now but a short distance in our front. Up this stream a big smoke can be seen; but the report of the Crows not being generally believed, it is supposed to be caused by Custer burning the village. A halt is made to await the infantry, and about this time General Gibbon arrives from the boat, which he reports is coming up the Big Horn without difficulty, with 160 tons of freight. The hills around us are barren and broken, growing little else but cactus. The infantry having arrived, the march is resumed. After marching 10.35 miles, the infantry having made 18.85, a halt is made on the Little Big Horn, in a pretty spot covered with fine grass, and surrounded with beautiful groves of cottonwood and ash. The river is about 20 yards wide, and 2½ feet deep. At 5 p. m. the march is resumed. Passing along the west bank of the Little Big Horn, our route lies through a beautiful valley carpeted with fine grass. After marching about 5 miles, twelve or fifteen ponies are picked up, and shortly afterward several Indians are seen hovering around our front. A long line

looking like cavalry, and three or four miles on our right and front is seen, by several officers through their glasses. One officer also sees something on the hills to the left looking like buffalo lying down. Night comes on before anything definite can be determined, but it is evident that General Custer has not been entirely successful. Having marched 6¾ miles from our last resting place, we go into camp at 8 p. m., in the middle of a grassy and pretty valley. Distance marched during the day by the infantry, 29.10 miles; by the cavalry, 17 miles. Whatever the result of the fight has been, every one anticipates another one to-morrow.

27th.—The night passed away quietly. Making an early start, we go but a short way when two tepees are seen through the timber, and crossing a narrow sandstone point (mentioned in the journal of April 29) we see just in front of us where a very large village was yesterday. The fate of Custer is now more puzzling than ever. We are not left much longer in suspense. Lieutenant Bradley sends in word he has counted one hundred and ninety-six dead cavalrymen lying on the hills to the left. What the officer saw yesterday looking like buffalo lying down are dead comrades and their horses. Soon two officers reach us from Colonel Reno, and tell us of their part of the action. "Where is Custer?" is asked them. "The last we saw of him he was going down that high bluff toward the lower end of the village. We do not know where he is now." They are told "We have found him." The Indians evidently left in a great hurry, leaving several lodges standing, and great numbers of buffalo-robes, blankets, tepee-poles, camp utensils, together with great quantities of dried meat and 50 or 60 ponies. After marching 8¾ miles we encamp on the Little Big Horn near Colonel Reno's position, which is on a high and steep bluff. The field and its incidents have been described too often to bear repetition here. An official map of it has been made by the chief engineer officer of the department. The fight taking place here reminds me of a taunt left by one of our Crow scouts not more than 3 or 4 miles up the valley during our scout over this same ground on the 29th of last April. Taking an abandoned hard-bread box and a piece of charcoal he covered it with a lot of drawings, which he said would tell the Sioux that we meant to clear them out, and then sticking a handful of green grass in the cracks, he added, "and this will tell them we are going to do it this summer." It is a little strange, considering the hundreds of miles we have marched over, that this taunt should have been left almost on the very spot where the one desperate fight of the campaign took place.

28th.—Most of the day is passed in burying the dead, bringing the wounded down from "Reno's Hill," and making hand-litters for them. At 6.30 p. m. the movement for the mouth of the Little Big Horn is commenced, but the difficulty of carrying the wounded by hand is so great that although the march is continued until midnight we only make 4.64 miles, and then go into camp on the river near what was the north end of the village.

29th.—Last night's experience having demonstrated the inefficiency of hand-litters, mule-litters are constructed to-day. A portion of the command is employed in burning the plunder found in the Indian camp, and as there are many wagon-loads of it the work takes most of the day. At 5 p. m. the march is resumed. Upon leaving camp it was only intended to proceed during the evening a few miles, but meeting two couriers 3 miles from camp, who inform us the boat is at the mouth of the Little Big Horn, it is decided to push on. After following the valley marched through on the afternoon of the 26th, for several miles, we turn to the left across some rolling hills and finally gain an elevated plateau. This plateau grows large cactus, and as the night is dark, it is very annoying to men and horses. The steamboat is reached after marching 14.9 miles. On account of the darkness it is only after much difficulty that a trail can be found leading down to the bottom near the boat. About 1 o'clock fires are built along a ravine, and by this means the wounded are gotten down and put aboard at 1.30 a. m. The *Far West* has been several miles farther up the Big Horn, and is now lying in that river, about half a mile above the mouth of the Little Big Horn.

30th.—The boat leaves about noon for our supply-camp, and General Terry being aboard, the command falls to General Gibbon. At 5 p. m. the entire command, including the Seventh Cavalry, cross the Little Big Horn and go into camp on its north bank, near the mouth, in a pretty camp among large cottonwood trees. From here to the supply-camp the route followed is nearly the same as the one used on our way up a few days ago. The following are the distances marched, (approximated.)

July *1st.*—Start at 5 a. m., march 20 miles, and camp on the Big Horn, where the infantry camped the night of the 25th.

2d.—Started at 4.30 a. m., march 23 miles, and crossing the Yellowstone on the boat, go into camp where we left the train. We remain in this camp until the 22d, waiting for re-enforcements and supplies. During this time the river falls about 4 feet. Part of the time the weather is very warm.

22d.—The command is moved to-day 4.38 miles down the river, to a camp where there is fine grass. The mosquitoes, however, nearly eat us up. We remain in this camp until the 27th. On the 24th there is a hard rain, and by next day the river has

risen nearly a foot. On the 25th General Crook is heard from. He is on Goose Creek, awaiting re-enforcements.

27th.—This morning at 11 o'clock camp is moved down the valley 4.06 miles to the second ravine mentioned in the journal of May 10th. The grass here is superb; the water, however, is poor. From this last camp we move to the mouth of the Rosebud, finding the roads good all the way, but the weather excessively warm. The following are the marches made, viz:

28th.—Start at 5.30 a. m., march 16.44 miles, and go into camp on the Yellowstone at 2 p. m.

29th.—Start at 5.15 a. m., march 22.9 miles, and camp on the Yellowstone at 4 p. m., about a mile from Bouyer's Spring.

30th.—Start at 5 a. m., march 15.1 miles, and camp on the Yellowstone, opposite the mouth of the Rosebud. Here we find four companies of the Sixth Infantry, two of the Seventeenth, and one of the Seventh Cavalry. The command remains in this vicinity until August 8th, awaiting supplies and re-enforcements. The river has fallen about 8 feet below high-water mark, and the boats commence to have trouble in shallow water.

On August 3d General Gibbon's command crosses the Yellowstone, and goes into camp on the south bank, on a high bench surrounded by still higher hills.

On the 7th the heat is terrible, the thermometer marking 116° in a tent. In the evening everything is ready to move next morning, about 1,700 strong.

For the purpose of abbreviating this paper, which has become already longer than originally intended, the journal form will be abandoned whenever convenient. The following are the marches made up the Rosebud, viz:

August *8th.*—Start at 5 a. m., march 9 miles, and camp on the Rosebud at 3 p. m., among large cottonwood trees.

9th.—Start at 5 a. m., march 10.91 miles, and camp at 5 p. m., where a very large Indian village has been some time during the spring.

10th.—Start at 5 a. m., march 15 miles, and camp with General Crook's command on Rosebud Creek.

Soon after leaving camp on the morning of the 8th we crossed the Rosebud, which is a miserable little creek about 15 feet wide, with muddy banks, and a soft bottom. In the lower part the water stands in pools. The valley, which is usually about one-half or three-quarters of a mile wide, grows good grass and quite a quantity of cottonwood timber. It is bordered on each side by sandstone bluffs, in which the strata is commonly horizontal. As we proceed up the stream the valley increases a little in width, while the timber diminishes in size. The water improves, and about 18 miles from the mouth begins to run. The creek, in the lower part especially, is very crooked, and the many crossings greatly delay our large trains.

On the 9th an exceedingly cold rain sets in, and continues the greater part of the day, but on the morning of the 10th it is again clear and pleasant.

At 11 a. m. of the 10th, those of our Indian scouts who are in advance come rushing back, crying "Sioux," and calling our attention to a large cloud of dust seen rising from behind a hill a few miles up the valley. That the Crows think the time has come at last to meet in fair battle their hated enemy is evident from their excited words and actions. They leap from their ponies and begin stripping for the fight, at the same time daubing their faces with paint. The squaws, even more excited than the men, go hurriedly to work saddling the "war-ponies," and all the time screaming and gesticulating in the wildest manner. A cavalry skirmish-line with one wing resting on the bluffs and the other in the timber is stretched across the valley, the infantry take position on the flanks, and the train is placed in the rectangle thus formed; the position is an admirable one, and the troops are eager and confident.

Soon the arrival of the famous "Buffalo Bill" puts an end to our warlike demonstrations, for he tells us the dust arises from General Crook's column, consisting of 25 companies of cavalry and 10 of infantry. Both commands encamp together on the Rosebud, and officers and men alike compare notes upon the campaign. On such occasions, when the long, tiresome, and continuous marches which have been made are the topic of the conversation, one appreciates the immensity of the country held by a few thousand Sioux—a country large enough to support millions of people. Here it is decided to send the wagon-train back to the Yellowstone under General Miles and his regiment of infantry. Upon reaching the river he is to patrol it on a steamboat, and prevent, if possible, the Sioux from crossing and escaping to the north. All the rest are to follow a tepee-trail found by General Crook's scouts, leading toward Tongue River. Fifteen days' rations are put on the pack-mules, and the march commenced. From this point on the Rosebud it is only 10 miles to Tongue River. The trail leads over a high divide which presents a steep face toward each stream, but the eastern side is especially precipitous. On the summit is an elevated and rolling prairie, dotted occasionally by a small grove of pines. In places the sandstone formation has been disturbed by volcanic action, and pieces of lava are scattered over the ground. The grass is magnificent and

of a variety known as "bunch-grass." A smell of sulphur coming from a ravine attracted attention to it, and going there I found a seam of coal on fire.

Tongue River is a fine stream, 75 yards wide and 2 feet deep; it has a rocky bottom and the water is clear and good. We marched down this river nearly 50 miles, still following the Indian trail. The greater part of the distance there is a little bottom on one side or the other, varying in width from one-half a mile to a mile, and always covered with the most luxuriant buffalo-grass. The hills on each side are very broken; in places they are of various colors, usually red. Where we reached the river there is a quantity of timber, cottonwood and ash, but about 25 miles down it becomes quite scarce, until just below the mouth of Pumpkin Vine Creek, where there is a great abundance. At this point there is an extensive and fertile valley, bordered by rolling hills. The citizen-scouts claim the trail is growing much fresher, and that it is only five days old when we reach Pumpkin Vine Creek; our Crows, however, maintain that it is at least nine.

The trail turns off to Pumpkin Vine, a short distance above where this muddy little creek joins Tongue River, and, following along it 6 or 7 miles through a country alternating with valley and bench land, crosses over to Powder River.

The divide lying west of this river is the roughest I have ever seen. It is composed of bad-land hills separated by yawning ravines hundreds of feet deep. Many of these hills are entirely destitute of any grass; even cactus refuses to grow on them.

Descending from this divide we reach a little bottom on Turtle or Mizpah Creek, in which the water is muddy and poor. This is doubtless due to the recent rains which have fallen almost incessantly for the past five days.

From where we cross Turtle Creek it is but a short distance to Powder River, which is about 100 yards wide and 2 feet deep. The water running over a sandy bottom is tolerably good, although by no means clear. The trail turned down this river and followed it to a point about 18 miles above its mouth, then turned to the right in the direction of the Little Missouri.

It being generally conceded that the Crows were right about the age of the trail, and that the Sioux are nearly two weeks ahead of us, we continue on down the river to the Yellowstone for the purpose of getting supplies.

The valley of Powder River is generally misrepresented; it is not all a hideous waste. We passed through several large and fertile bottoms growing fine buffalo-grass. In many places this has been burnt off by the Sioux, intending by this means to secure their retreat; and had it not been for the many heavy rains in the past two weeks they doubtless would have succeeded in making it an almost impossibility to pursue them. As it is, many of General Crook's cavalry-horses are on their last legs. The bluffs on each side are very precipitous and often present a bad-land face, yet on top they are generally covered with good grass. Large cottonwood timber grows almost everywhere along the banks.

The river seems extremely sensible to every rain, rising and falling in rainy weather sometimes twice a day with a variation of at least 18 inches. Its bottom is everywhere soft, and in places quicksand.

The following are the distances marched each day since leaving the Rosebud on the 11th:

August 11th.—Start at noon, march 12.45 miles, and camp on Tongue River. During the evening there is a severe rain-storm.

12th.—Start at noon, march 12.64 miles, over heavy roads; camp on Tongue River at 6 p. m.; during the day there have been occasional showers.

13th.—Start at 7 a. m., march 24 miles, and camp on Tongue River at 6 p. m.; during the afternoon and evening there is a hard rain.

14th.—Start at 5 a. m., march 14 miles, and camp on Pumpkin Vine Creek,

15th.—Start at 5.40 a. m., march 20.28 miles, and camp on Powder River at 3 p. m.

16th.—Start at 5.55 a. m., march 19 miles, and camp on Powder River at 3.30 p. m.

17th.—An early start, march 24.10 miles, and camp on the Yellowstone, near the mouth of Powder River. We remained in this last camp until the 25th, getting supplies, and recruiting the strength of the men and animals.

The weather is very rainy, causing a rise in the Yellowstone of over a foot. In this river, about 2½ miles below the mouth of Powder River, are the Wolf Rapids, offering, just before the rise mentioned, considerable difficulty to steamboat navigation. The expense of making them navigable at all seasons when the river is low would be very little, either by removing the obstructing rock or by building a wing-dam so as to utilize all the water.

The valley on the Yellowstone at this point is large and fertile, and hemmed in by rolling and grassy hills. On the opposite side there are a mass of bad lands, back of a little bottom.

On the morning of the 24th, General Crook's command starts up Powder River to pick up and follow the Indian trail. The command belonging to the Department of Dakota followed the next day, and, marching 17.1 miles, goes into camp, part on the river and the rest on a little creek. This evening Buffalo Bill brings news from Lieutenant

Rice, opposite the mouth of Glendive Creek, that the Indians are hovering around there. For fear that they may escape north, General Terry turns in that direction. The next morning, the 26th, General Crook with his command is to follow on along the trail.

Instead of returning to the mouth of Powder River, we move obliquely to the Yellowstone, over a high hilly country, where the grass has been lately burnt off, and reach the river just above O'Fallon's Creek, and camp there. Distance 22.4 miles.

The grass along the route has evidently been very fine. The hills are entirely destitute of timber, and are only suitable for pasturage.

O'Fallon's Creek, swollen by the recent rains, is 30 feet wide and nearly 3 feet deep. Crossing the Yellowstone about 6 miles below our camp of last night, we set out on a long march toward the Missouri divide.

Leaving the river at 6.40 p. m., on the evening of the 27th, we proceed a short distance down the stream, and then turn to the left and follow a large buffalo-trail leading a little west of north, through pretty hills covered with good grass. The moon is about half full, and the weather being fine, the march is an exceedingly pleasant one. After traveling 6.25 miles, a halt is made on the prairie for the night.

The following are the distances made on each day of the march, from here to a point opposite the mouth of Glendive:

August 28th.—Start at 5 a. m., march 20.95 miles, and camp on Bad Route Creek.

29th.—Make an early start, march 17.36 miles, and camp on Rush Creek.

30th.—March 17.50 miles, and camp on Deer Creek.

31st.—March 13.26 miles, and camp on the Yellowstone, near the mouth of Deer Creek.

I have always heard the country passed over during these marches described as a bad-land waste, but such an idea is a very great mistake; it is one of the finest grazing districts in the world. In all the distance traveled, about 70 miles, not more than 10 took us through a poor country, and that was on the lower end of Deer Creek. Our course was first northwest to the head of Bad Route, then northeast to Deer Creek, and thence down that creek, running southeast, to the Yellowstone. The country is a series of long waving hills, thickly carpeted with magnificent grass, and separated by valleys which descend from them in gentle declivities. There was some difficulty in finding water, and yet we always had enough. I do not doubt but that our ignorance of the country accounts better for our trouble in finding water than its scarcity does. When compared with districts around the base of a granite mountain it cannot be called a well-watered country; yet 1,200 men, not one of whom knew the ground, marched through it with as many animals, and never wanted for water. The pebble-drift scattered over the elevated prairies farther up the river, and which causes the grass to be thin, entirely disappears here. It is destined to be some day a favorite stock country, for certainly it is capable of furnishing pasturage for immense herds of cattle.

Antelope and buffalo were seen in great numbers. On the 29th, striking a large buffalo herd, a grand hunt took place. Permission being given to many to join in the sport added additional excitement to the chase. About a dozen were killed, making many a man look well pleased at the prospect of plenty of fresh meat. Just after this hunt the Second Cavalry was ordered to cross the divide in the direction of the Dry Fork, and then turn and travel east. The object of this movement is to examine the trails on the northern slope.

The officers represent the country as a good one. The battalion returned the next morning without having seen any fresh Indian signs. Upon our arrival at Glendive we were pretty well convinced that the Indians had gone to the Little Missouri, having broken up into small parties. This opinion was strengthened three days later upon the return of the Seventh Cavalry, which left us on the head of Deer Creek and scouted down to the mouth of the Yellowstone without seeing a fresh trail. The country across the Yellowstone is a high rolling prairie, apparently growing good grass.

The mouth of Glendive Creek lies about a mile above camp; on each side of it there is a little bottom. Along this portion of the Yellowstone there is but little timber, indeed it is scarce all the way below Tongue River. A few miles back from the river small but straight cottonwood and ash timber is found, but not in sufficient quantities to be of much service. At one camp, the night of the 29th, we were obliged to use buffalo chips.

The river has fallen so much that the boats have great difficulty in navigating it, and it is believed that, unless some of the troops are sent home, it will be impossible to supply the Tongue River post. As the Montana troops have the greatest distance to march, they are ordered to return home and start on the morning of September 6.

The country from Deer Creek to York's River is much the same as that traveled over on our scout out towards the divide.

Our route, upon starting, takes us through a fair and large valley on the Yellowstone, opposite the "stockade" built by General Stanley in 1873. I observed while passing through this bottom that Turtle Creek is laid down wrong on the maps. It joins the Yellowstone 5.92 miles from Deer Creek (measured along the wagon-road) and not near the "stockade."

West of York's River the country grows rapidly rougher, and following down Custer's

Creek one travels through a hideous mass of bad-lands. The utter waste of such a country passes the understanding of those who have not seen it. Huge hills of sandy clay and earth-like ashes, entirely destitute of grass, brush, or even cactus, which would be a fitting companion, lie thrown together in all imaginable shapes. Some a hundred feet high are not any wider at the base, and only an inch or two thick at the summit. In places the gray sandy clay, looking almost like sandstone, but so soft that one can mold it in the hand like mud, stands with sides almost vertical.

When one begins to wonder why these hills do not follow the laws of gravity and fall, he concludes that it is because every thing around is utterly without law or order. In other places little mounds of chalky clay, nearly pure white, are carved out by the winds and water into the most fantastic shapes. Various shapes and various kinds of earth are tumbled together in one confused mass. From the mouth of this creek we proceed on to Union Creek, where we turned back on the 10th of last June.

In the hills, a short way up the river from Custer Creek, I observed several fine seams of coal, and not far from this volcanic rock scattered around.

On the bad-lands, 9.92 miles from Custer Creek, we made a camp in a little bottom on the river, on the opposite side of which is a large and beautiful terraced valley. The next day we reached Union Creek, after marching about 8 miles, and from there followed our old trail from Fort Ellis with three exceptions; one was just above Fort Pease. Upon arriving at the ford, 8 miles above that place, we found we could not cross the river without wetting every thing in the wagons; this forced us to take the rough hills mentioned previously in this journal as lying opposite Pompey's Pillar. We did not strike the old trail again until within 3 or 4 miles of Baker's battle-ground. The district thus passed over, about 60 miles by the wagon-road and 40 in a straight line, is a poorly watered and barren waste. In all this distance we crossed but one running creek, Willow Creek, about 15 miles above Fort Pease. The second place was from the supply camp to countryman's ranch, again finding the river too deep for the wagons.

Passing into the hills to the north, we soon reached White Beaver Creek, and then passed over high rolling hills, covered with good grass, and in many places with fine forests. Sweet Grass Creek, a clear mountain stream, is also crossed just below Big Timber. The infantry turned to the north to reach Camp Baker and Fort Shaw, via the Forks of the Musselshell. The cavalry reached Fort Ellis on the 29th day of September. The infantry reached Camp Baker on October 2d, and Fort Shaw on the 6th

The following are the distances marched each day on way from Glendive Creek. home, viz:

September 6th.—Started at 10.30 a. m., marched 13.96 miles, and camped at 3.30 p. m. on a ravine putting into the Yellowstone not far above the stockade. Here we found water in holes.

7th.—Start at 6 a. m., march 6 miles to Rush Creek; to Bad Route Creek, 18.26, (here we noon;) to camp, 6.30 p. m., on a dry ravine, 25.12 miles. Hard rain, lasting from 3 p. m. until midnight.

8th.—Start at 7.15 a. m., march 15.32 miles, and camp on York's River at 1.30 p. m. Occasional showers during the day.

9th.—Start at 6 a. m., march about 15 miles to Custer Creek, and 26.97 miles to camp at 5 p. m. at the mouth of Custer Creek; the roads are very heavy.

10th.—Start at 12.20 p. m., march 9.92 miles, and camp on the Yellowstone at 4 p. m.

11th.—Start at 7.20 a. m., march 21.8 miles, and camp on Sandy Creek.

12th.—Start at 7.45 a. m., march 5.4 miles and camp on the Yellowstone just above and across the river from the new post.

13th.—Start at 7 a. m., march 20.67 miles, and camp on the Yellowstone at 2.30 p. m.

14th.—Start at 7 a. m., march 21.68 miles, and camp on the Yellowstone at 3.15 p. m., at the mouth of the Little Porcupine. The water in this creek is now clear and good.

15th.—Start at 7 a. m., march 16.76 miles, and camp on the Yellowstone, above the Great Porcupine.

16th.—Start at 7 a. m., march 18.57 miles, and camp on the Yellowstone, above "Froze-to-Death Creek."

17th.—Start at 7.05 a. m., march 23.72 miles, and camp on the Yellowstone, 7 miles above Fort Pease, at 4 p. m.

18th.—Remained in camp.

19th.—Start at 7 a. m., march 25.18 miles, and camp on a ravine, where water stands in holes, at 5.30 p. m.

20th.—Start at 6.30 a. m., march 7.9 miles to the Yellowstone, opposite Pompey's Pillar, and then on to camp on the river. Total distance, 30.62 miles. The wagons did not arrive until 7.30 p. m.

21st.—Start at 9 a. m., and camp just above Baker's battle-ground. Distance, 10.29 miles.

22d.—Start at 6.45 a. m., march 22.75 miles, and camp on the Yellowstone at 3.30 p. m., a little ways above the mouth of Clark's Fork.

23d.—Start at 7 a. m., march 20.52 miles, and camp on the Yellowstone at 2.15 p. m., at the old supply camp.

24th.—Start at 7 a. m., march 20.66 miles, and camp on the Yellowstone at 4 p. m.

25th.—Start at 7.15 a. m.; take the back trail for 2.17 miles. From camp to White Beaver Creek it was 8.27 miles, and to camp, near some small springs, 16.70 miles.

26th.—Start at 7.05 a. m.; after marching 8.87 miles we reach Sweet Grass Creek, and 17.56 miles brings us to the Big Timber.

The infantry turns to the north about 1 mile below the last-named creek. The cavalry crosses the Big Timber, and goes into camp on the Yellowstone. Total distance, 18.63 miles.

27th.—Start at 6.35 a. m., march 14.09 miles, when we reach Gage's Ford, where we noon. Duck Creek is 1.20 miles farther, or 15.29 from this morning's camp. Warm Spring Creek, 18.54, and camp on the Yellowstone, near Countryman's old ranch, 25.64 miles.

28th.—From camp to Shields's River, 8 miles, and to camp on Billman's Creek, 26.6 miles.

29th.—To Fort Ellis, 11.28 miles.

Total, from the camp opposite Glendive Creek to Fort Ellis, 448.76 miles.

The following are the marches made by the infantry on their way from the Yellowstone to Fort Shaw:

September 26th.—From camp to camp on White Otter Creek, 21.99 miles.

27th.—From camp to camp on Sweet Grass Creek, 20 miles.

28th.—From camp to camp on Big Creek, 23.72 miles.

29th.—From camp to camp on Musselshell River, 21½ miles.

30th.—From camp to camp on Six-Mile Creek, 25 miles.

October 1st.—From camp to camp at Warm Spring, 7½ miles.

2d.—From camp to camp at Camp Baker, 16.9 miles.

3d.—From camp to camp on Cottonwood Creek, 19.5 miles.

4th.—From camp to camp on creek between Hough Creek, 18¼ miles.

5th.—From camp to camp on the Missouri at the ford, 24 miles.

6th.—From camp to camp at Fort Shaw, 20¼ miles.

Total, 218.97 miles.

Total from Glendive Creek to Fort Shaw, 585.58 miles.

Total marched by the united command from Fort Ellis to camp of September 25, 1,288.42 miles.

Total march by the infantry as a battalion from March 17 to October 6, 1,687.39 miles.

Total march by the Second Cavalry as a battalion from April 1 to September 29, 1,393.21 miles.

To the amount marched by the infantry, 208.14 miles wants to be added for the company commanded by Major Freeman, 247.18 for the company commanded by Lieutenant English, and 186.24 miles for Captain Sanno's.

To the amount marched by the cavalry, 306 miles is to be added for F Company, Lieutenant Roe in command; 352.50 for G Company, Captain Wheelan; 404.50 for L, Lieutenant Hamilton; and 388 for H, Captain Ball.

In conclusion, it might be said that the country marched over, taken as a whole, is a good one. Along the Yellowstone and its tributaries are many large and fertile valleys, only waiting for the hand of man to make them bloom with golden crops. Back of these valleys are rolling hills, covered with the most luxuriant and nutritious grasses, and as a grazing district challenging superiority.

The Yellowstone River has been thoroughly tested, and the trial has resulted in proving it navigable. The expenditure of a little money in removing the Wolf and Buffalo Rapids, and confining the water in one channel in several other places, would do away with all difficulty, from the 1st of June until the 1st of October, to a point near the mouth of the Big Horn. The facility with which it can be used for supplying its lower districts, by Mackinaw boats from Benson's, at an expense immensely less than by wagon-trains, has also been proved this last summer.

E. J. MCCLERNAND.
Second Lieutenant Second Cavalry,
Acting Engineer Officer, District Montana.

REPORT OF LIEUTENANT GEORGE D. WALLACE, SEVENTH CAVALRY.

SAINT PAUL, MINN., *January* 27, 1877.

SIR: I have the honor to submit the following report of the march and the country passed over by the Seventh Regiment of Cavalry from the 22d to the 25th of June, 1876:

At 12 m. on the 22d of June, 1876, the Seventh Cavalry, under Lieutenant-Colonel Custer, left camp on the Yellowstone and moved up that stream for 2 miles to the mouth of

the Rosebud, then up the Rosebud. We crossed the latter near its mouth. It was a clear running stream, from 3 to 4 feet wide, and about 3 inches deep; bottom gravel, but in many places water standing in pools. Water slightly alkaline. Owing to delays with the pack-train the command moved only about 12 miles that day. We camped on the left bank of the Rosebud, at the base of a steep bluff. We had plenty of wood and water, and grass for our animals. During the greater part of the march the trail followed the high ground, or second bottom, where the soil was poor, the grass thin, and crowded out by sage-brush and cactus. In the lower part of the valley the soil appeared to be good, the grazing fair, the bottom timbered with large cottonwood. Small willows grew thickly along the banks in many places. For the first 8 miles the hills sloped back gradually, but near camp were more abrupt, and covered with stones and cactus. Several deep ravines were crossed during the day. The only serious obstacle to a wagon-train would be the numerous crossings of the bends of the Rosebud. Weather clear, but not unpleasantly warm. No game visible. Plenty of fish in the creek.

June 23, 1876.—Orders were given last night that trumpet-signals would be discontinued, that the stable-guards would wake their respective companies at 3 a. m., and the command would move at 5 a. m. General Custer stated that short marches would be made for the first few days, after that they would be increased. All were ready at the appointed time, and the command moving out we crossed to the right bank of the Rosebud. The bluff being very broken, we had to follow the valley for some distance, crossing the Rosebud five times in 3 miles; thence up the right side for about 10 miles. There we halted, to allow the pack-train to close up. Soon after starting, crossed to the left bank and followed that for 15 miles, and camped on right bank at 4.30 p. m., making a distance of over 30 miles. The last of the pack-train did not get into camp until near sunset. About 5 miles from our last camp we came to the trail made by Major Reno, a few days previous, and a few miles farther on saw the first traces of the Indian camps. They were all old, but everything indicated a large body of Indians. Every bend of the stream bore traces of some old camp, and their ponies had nipped almost every spear of grass. The ground was strewn with broken bones and cuttings from buffalo hides. The country passed over after the first few miles was rolling, and a few deep ravines the only obstacle to hinder the passage of a wagon-train. Soil poor, except along the creek. Grass all eaten up. Plenty of cottonwood along the creek. During the last 5 or 6 miles of the march, the cottonwood timber was gradually replaced by ash and a species of elder. The valley was about one-fourth of a mile wide, and for the last 15 miles the hills were very steep and rocky, sandstone being present. The country back from the hills looked to be very much broken. The hills were covered with a short growth of pines. No game seen during the day; weather warm and clear.

June 24, 1876.—The command moved at 5 a. m. this morning. After we had been on the march about an hour, our Crow scouts came in and reported fresh signs of Indians, but in no great numbers. After a short consultation, General Custer, with an escort of two companies, moved out in advance, the remainder of the command following at a distance of about half a mile. We followed the right bank of the Rosebud; crossed two running tributaries, the first we had seen. At 1 p. m. the command was halted, scouts sent ahead, and the men made coffee. The scouts got back about 4, and reported a fresh camp at the forks of the Rosebud. Everything indicated that the Indians were not more than thirty miles away. At 5 p. m. the command moved out; crossed to left bank of Rosebud; passed through several large camps. The trail now was fresh, and the whole valley scratched up by the trailing lodge-poles. At 7.45 p. m. we encamped on the right bank of Rosebud. Scouts were sent ahead to see which branch of the stream the Indians had followed. Distance marched to-day, about 28 miles. Soil in the valley very good, and in many places grazing very fine. Timber scattering, principally elder and ash. Hills rough and broken, and thickly covered with pines. Weather clear and very warm. About 9 p. m. the scouts returned and reported that the Indians had crossed the divide to the Little Big Horn River. General Custer determined to cross the divide that night, to conceal the command, the next day find out the locality of the village, and attack the following morning at daylight. Orders were given to move at midnight, but we did not get off until near 1 a. m., and, owing to delays on account of pack-train, we had only marched about 8 miles when daylight appeared. We halted, and the men were ordered to make coffee. While waiting here a scout came back from Lieutenant Varnum, who had been sent out the night before. In a note to General Custer, Lieutenant Varnum stated that he could see the smoke of the village about 20 miles away, on the Little Big Horn. The scout pointed out the butte from which the village could be seen. It was about 8 miles ahead.

We moved on, and when near the butte Lieutenant Varnum joined us and reported that the Indians had discovered the command and that he had seen couriers go in the direction of the village. General Custer assembled the officers, told them what he had heard, and said he would move ahead and attack the village without any further delay.

At 12 m., on the 25th, we crossed the divide between the Rosebud and Little Big Horn. From the divide could be seen the valley of the Little Big Horn, and about 15 or 20 miles to the northwest could be seen a light blue cloud, and to practiced eyes showed that our game was near. A small stream starting from the point near where we crossed the divide flowed in the direction of the smoke. After the assignment of battalions was made, General Custer followed down the right bank of this stream, and Major Reno the left. When within three miles of Little Big Horn, Major Reno was ordered across to the right bank and the two columns moved together for some distance, when Major Reno was ordered ahead. He recrossed this stream, moved down it, crossed the Little Big Horn, halted his column, formed line and moved down the valley and commenced the battle of June 25.

In passing from the Rosebud to the Little Big Horn, we followed up the left branch of the first, then up a dry ravine to the crest of the divide; grass short, soil poor, hills low. From the crest to the Little Big Horn the country was broken and the valley narrow; some timber along the little stream we followed down. Distance traveled during the night of the 24th and on the 25th about 6 miles.

I am, sir, very respectfully, your obedient servant,

GEO. D. WALLACE,
First Lieutenant and Adjutant Seventh Cavalry.

The CHIEF ENGINEER
Department of Dakota.

REPORT OF SERGEANT JAMES E. WILSON, BATTALION OF ENGINEERS.

HEADQUARTERS DEPARTMENT OF DAKOTA,
CHIEF ENGINEER'S OFFICE,
Saint Paul, Minn., January 3, 1877.

SIR: I have the honor to submit the following report:

In obedience to orders received from you in the field, I remained on the steamer Far West during its trip up the Big Horn River, for the purpose of making a boat survey, and collecting information in regard to the nature of that stream and the adjacent country.

June 24.—Immediately after the departure of General Terry and staff, at 6.30 p. m., the boat moved up a short distance and wooded, after which it crossed over and tied up on the left bank of the Yellowstone River.

Two Indian curs were seen this evening in close proximity, but were not molested. The escort commanded by Capt. S. Baker and First Lieut. J. Carland, Sixth Infantry, was composed as follows: Company B, Sixth Infantry, to which were attached some soldiers left in charge of property belonging to the absent portion of the command. A few sick men, in charge of Hospital Steward Dale, occupied the rear portion of the cabin-deck. These with first-class private Thomas Culligan and myself of the engineer detachment made up the total commissioned and enlisted on board. The whole fighting force, including the armed civilians on board, did not exceed 60 men.

June 25.—At 12 m. the boat moved up the Yellowstone, and at 12.35 p. m. reached the mouth of the Big Horn. The country on the right bank of the Yellowstone at this point is quite level for a considerable distance, and thickly timbered with cottonwood. The Big Horn is about 150 yards wide at its mouth, with a depth of from 3 to 8 feet. Tullock's Fork enters the Big Horn on its right bank, about 4 miles from its mouth. Reached Josephine Island at 4.50 p. m. It is well timbered, and about three-fourths of a mile long, and situated about 12 miles from the mouth of the river. The river at a point about a mile above Josephine Island spreads out to a width of 500 or 600 yards, causing a shallow channel. The current is swift, and the bed of the river studded with numerous islands and sand-bars.

After a travel of 15 miles the first creek entering the Big Horn on its left bank was reached. About one mile further on the boat tied up, at 8.30 p. m., on the left bank. The current of the Big Horn is much swifter than that of the Yellowstone, with a depth varying from 3 to 8 feet; 5¼ feet of water at Josephine Island. Rapid water was encountered on two occasions during the day's travel. The country as we advance becomes richer, the hills on the right bank close gradually in, and the left bank is low, thickly timbered, and well grassed. Game appeared to be abundant in the valley, as we saw a herd of 8 elk on the right bank in the afternoon. Passed many old Indian encampments. Heavy rain fell during the night. Pine timber was obtained at the point where the boat was tied up. Maximum thermometer, 91°; minimum thermometer, 63°. Bearings were taken by prismatic compass; the rate of the boat carefully noted whenever a change was observed, and at intervals not greater than 10 minutes. Whenever rapids were encountered the distance to the end of the course was estimated. Readings of the barometer and thermometer were taken each day. Mean solar chronometer 1362, Arnold and Dent furnished the time. The means used to ascertain

the rate of the boat were as follows: By selecting two objects near the river immediately in line, and keeping them in line by walking toward the stern of the boat. The rate of the walk determined the rate of the boat.

June 26.—Started at 3.30 a. m. Two hours later reached a creek entering the Big Horn on its right bank, and a short distance further on we encountered the first rapids. Here a long delay was occasioned. At 1 p. m. the hills on the right bank closed in up to the water's edge, rising to a height of 150 feet, and in some places to 200 feet. The river valley on the left bank still low and thickly timbered with cottonwood, the hills on the right sparsely timbered with pine. Passed General Terry's camp, of June 25, at 9.30 a. m.; fires still smoldering. Tied up on the west side of a large island near the right bank at 9 p. m., after an estimated travel of 29 miles. The day was beautiful and clear, and the country passed through extremely rich and fertile. No game, however, was seen to-day. The Big Horn Mountains were in view about 75 miles to the south and towering to the clouds. As we ascended the river the channel became narrower and deeper and more easily navigated. The ridge of hills on the right bank extended for a distance of 8 miles. They are all washed and of a dark color; bare and destitute of any vegetation, excepting some small quantities of pine in the cañons and ravines. At 8 p. m. the clouds toward the west looked dark and threatening, but they soon cleared away. Maximum thermometer, 70°; minimum thermometer, 60°. Rapid water was encountered many times. Old Indian encampments were met with at nearly every bend of the river. Concerning the fertility of this region, Mr. Hall, an experienced western farmer, stated that he would rather have a farm on the Big Horn River than any other place he knew of. Mr. Hall was on board the Far West during the trip, and the further the boat ascended the more profuse was he in his praises of the country.

June 27.—Boat started at 3.30 a. m., but at 6 a. m. very little had been accomplished, owing to the shallowness of the channel and swiftness of the current. Two chutes were tried without success. An ascent of the third was, however, accomplished after considerable trouble and delay. A little further on the site of Fort C. F. Smith became visible about 35 miles distant. The second ridge of high hills on the right bank was reached at 9 a. m., rising to a greater height, but bearing the same appearance, except that this ridge is more broken, and two of its peaks rise to a height of fully 300 feet above the water's edge. Mountain-sheep 15 in number, were seen on this ridge. Ridge about 3 miles long. The valley on the left bank bears the same rich, park-like appearance, the scenery splendid, and the river studded with large, beautiful, heavily-timbered islands.

A short distance above the southern extremity of the second ridge, the Li tle Big Horn River enters the Big Horn on its right bank. This point was reached at 10 a. m. The valley of the Little Big Horn is well timbered, and about 1¼ miles wide at this point. Near the mouth of the stream are many dangerous quagmires. A delay of two hours was experienced here while Captain Baker and his company proceeded to the summit of the ridge of bluffs on the south side of the Little Big Horn Valley for the purpose of reconnoitering. Started at 12.35 p. m., and continued up the Big Horn River; travel slow and very difficult, and the water very rapid.

About 2.30 p. m. the third ridge of hills on the right bank was reached, bearing the same appearance as the others and of the same height as the second ridge. Allowing the river to be about 3,300 feet above sea-level, then the respective altitudes of the three ridges would be 3,500, 3,600 and 3,600 feet. This is a rough estimate, but I think an approximate one. Above the upper ridge the river-channel becomes wider and much cut up with small islands. At 5.30 p. m. Sitting Bull's Rapids were reached, and one hour occupied in ascending them. Very soon afterward a series of rapids were encountered, extending in quick succession a distance of fully 3 miles, over which it was found impossible to force a passage. The boat accordingly dropped to the foot of these rapids and tied up on the right bank at 8.30 p. m., after an estimated travel of 21 miles. Total estimated distance from the mouth of the Big Horn River about 66 miles.

From Sitting Bull's Rapids the hills on the right bank wheel sharply away from the river, and from our present camping-place a good view on both sides is obtainable. Elk abound in this part of the country, their favorite resorts being the grassy and well-shaded islands along the river. During the day's travel, similar features to those of yesterday presented themselves. Maximum thermometer, 76°; mimimum thermometer, 63°.

June 28.—The ascension of the rapids was again tried this morning but without success, and consequently the further navigation of the river was abandoned. The passage back to the mouth of the Little Big Horn was made in a very short time—the current forcing the boat right around so that the stern led the way on many occasions, and the downward run accomplished in a whirling, revolving manner, by reason of which the boat must have sustained considerable damage. Remained at the mouth of the Little Big Horn all day.

An Indian scout named "Curley" (known to have been with General Custer) arrived

about noon with information of a battle, but there being no interpreter on board very little reliable information was obtained. He wore an exceedingly dejected countenance, but his appetite proved to be in first-rate order. Elk and deer killed here. Good fishing.

June 29.—Three scouts arrived during the day with the news of the disastrous battle of the Little Big Horn. The Far West was immediately barricaded, and preparations made to receive the wounded on board. At 10 p. m. the van of General Terry's command arrived. The main column with the wounded did not arrive until 1 a. m., June 30.

I am, sir, very respectfully, your obedient servant,

JAMES E. WILSON,
Sergeant of Engineers.

Lieut. E. MAGUIRE,
Corps of Engineers, U. S. A., Chief Engineer Department of Dakota.

APPENDIX Q Q.

ANNUAL REPORT OF CAPTAIN W. S. STANTON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF THE PLATTE.

HEADQUARTERS DEPARTMENT OF THE PLATTE,
ENGINEER OFFICE,
Omaha, Nebr., June 30, 1877.

GENERAL: I have the honor to submit the following annual report, as engineer officer of this military department, for the fiscal year ending June 30, 1877:

At the beginning of the year I had returned to Fort Fetterman from a reconnaissance to the Tongue and Rosebud Rivers with the column of General Crook, operating against the Sioux Indians, and at once commenced a reconnaissance of the routes in the department for the purpose of carefully locating them and the military posts on a revised map; of securing correct distances for use in payments for transportation and mileage; and, for publication in a form convenient for use, such information regarding the character of routes and quality of roads as is needed in conducting the movements of troops and transportation of supplies.

I had with me a party consisting of one civilian draughtsman, who performed the duties of topographer and time-keeper, and three enlisted men.

During the months of July and August the following routes, aggregating between 500 and 600 miles, and the following reservations were surveyed, viz:

ROUTES.

From Fort Fetterman to Fort Laramie, via southwest bank of North Platte River.

From Fort Fetterman to Fort Laramie, via northeast bank of North Platte River.

To Fort Fetterman new wood reservation.

Cut-off route between routes from Fort Laramie to Cheyenne and to Fort Fetterman.

From Fort Laramie to Camp Robinson.

From Camp Robinson to Camp Sheridan.

From Camp Robinson to Sidney Barracks.

RESERVATIONS.

A new wood reservation for Fort Fetterman, on La Bonté Creek, in the northeast part of the Black Hills of Wyoming. This reservation

contains two square miles of very hilly land, much broken by deep ravines, and, excepting occasional openings, is thickly timbered with pine, the largest trees occasionally having a diameter of 15 or 20 inches.

The military reservation of Camp Robinson, containing 7⅓ square miles, lying between White River and the crest of Soldiers' Grove Bluffs, and embracing the valley of a small brook called Soldiers' Creek.

The military reservation of Camp Sheridan, containing 2⅓ square miles, lying on both sides of Beaver Creek.

In July the longitude of Fort Fetterman was determined by telegraphic time-signals exchanged with the Lake Survey observatory at Detroit, the local time and latitude of the post being determined with a sextant, as the office is not supplied with an astronomical transit.

Meteorological observations with the cistern barometer and psychrometer, at hours corresponding to those of the signal-service observations at Cheyenne, and with the maximum and minimum thermometer, were taken by privates William W. Matthias and Samuel Ashton, Twenty-third Infantry, respectively at Fort Fetterman and Fort Laramie, from June until September and October. These men performed this duty apparently with much care, keeping very neat and apparently accurate records. Their observations and those taken on the march will be reduced, and the results reported in connection with those to be taken in the same localities this season.

On the march numerous observations were taken with an aneroid barometer.

Unfavorable weather for astronomical observations at Fort Fetterman, the precautions necessary against Indians during a season of active hostilities in a region always much infested by them, and owing to the exigencies of the campaign against the Sioux, the extreme reduction in men and transportation at the posts from which both had to be supplied for the reconnaissance, contributed to retard and embarrass the foregoing work.

Finally the discharge, in the midst of work in the field, of my topographer and time-keeper, in consequence of the refusal by Congress of an appropriation from which he could be paid, left me with only two enlisted men as assistants, who were charged with the barometrical and odometer readings, and without a single person of any previous experience on a survey or reconnaissance, or in the use of the simplest instrument.

On reaching Sidney, on the 1st of September, field-work was necessarily abandoned for the rest of the season.

In November a tract of land, set apart by the Secretary of War from the military reservation of Camp Douglas for a public cemetery for Salt Lake City, pursuant to an act of Congress, was surveyed and its boundary and subdivision lines established.

During the winter the field-notes and astronomical observations taken on the 900 miles of reconnaissance made by me between May and September, 1876, have been reduced and computed. The collection of information from various sources for a revision of the maps of the department has advanced as rapidly as the means available would permit.

A considerable mass of information has been collected from the office of the chief-engineer of the Military Division of the Missouri, the Adjutant-General of the Army, and the General Land-Office, for the purpose of forming in this office a complete record of the various tracts of public land within the department which, for military purposes, have from time to time been reserved, extended, reduced, or relinquished, and regard-

ing which no complete record in a form suitable for convenient reference has hitherto existed at these headquarters.

The boundaries and names of all the military departments and Indian reservations in the United States west of the Mississippi River have been indicated in water-colors on 15 mounted copies of the "Map of the Territory of the United States from the Mississippi River to the Pacific Ocean," for the use of the various staff-officers in the department.

Sixty plots and tracings of topographical drawings have been made.

During the year 1,660 maps and 191 printed reports, many of the latter containing maps, have been issued in detail, as shown by the following statement:

MAPS.

	No.
Raynolds and Maynadier's revised map, eastern sheet	513
Raynolds and Maynadier's revised map, western sheet	472
Sheet No. 3, Western Territories, Gillespie	389
Wyoming	111
Wyoming, mounted	16
Nebraska	19
Nebraska, mounted	16
Lieutenant Wheeler's atlas-map	63
Dakota	13
Montana, eastern sheet	13
General Warren's map	13
Kansas, Texas, and Indian Territory	1
Territory of the United States, Mississippi River to Pacific Ocean	17
Map of the United States showing limits of departments and positions of posts.	4
Total	1,660

REPORTS.

	No.
Annual report of engineer officer Department of the Platte, 1876	101
Annual report of engineer officer Department of Dakota, 1876	15
Captain Raynold's Exploration of Yellowstone and Missouri Rivers	5
Lieutenant Warren's Explorations in Nebraska and Dakota	2
Captain Jones's Yellowstone Park	3
Captain Ludlow's Yellowstone Park	56
Lieutenant G. M. Wheeler's report of 1876	9
Total	191

The increase in the number of troops in the department, the active military operations of the year, and the public interest in the regions of the Black Hills and Big Horn Mountains, have very much increased the demand for maps and explains the unusually large issue.

During the year the work of a draughtsman in the office has been done by Private Charles Holtes, Fourth Infantry, for $28 per month, in full of all pay and allowances, until his discharge in May, in the reduction of the Army, because of the failure of the Army appropriation bill at the last session of Congress. Although without previous experience or instruction, faithful attention and industry merited for him, while subjected to the increased expense of living here, at least a fair compensation or adequate means of support.

I respectfully and earnestly renew the recommendation made in my previous annual reports, that a detachment of selected enlisted men be provided for service on surveys and reconnaissances in this department.

The want of such a detachment is constantly felt; is a serious embarrassment in making important reconnaissances and special surveys, and leaves me powerless to secure compass and odometer surveys or horseback reconnaissances of the routes taken by columns and detachments of troops in their movements through the department, made with suffi-

cient care and noted with sufficient clearness to be of any value for mapping purposes. Opportunities of securing such surveys of lines running across areas either incorrectly mapped or not mapped at all, are thus frequently lost.

The requisite instruments have been supplied from this office to all the posts in the department for this purpose.

Although the running of such a simple reconnaissance-line with the march of a detachment or column through an incompletely mapped region is a normal military duty, when not precluded by the object or circumstances of the march, it is not generally so regarded by the officers in the department. Unless the authority of the department commander should be vigilantly exercised in rigorously exacting this duty of officers the detachment of specially-instructed men would need to be sufficiently large for distribution among a few central points in the department from which one or two of its members could quickly join a column when beginning its march, otherwise this important and desirable work will have to continue, as hitherto, utterly neglected. That such a method, so inexpensive, of covering the department with a net-work of such lines, roughly surveyed it is true, but nevertheless of much value in perfecting a map of a large area of country for practical military purposes or popular use, should be disregarded and neglected, is to be regretted extremely in a nation skeptical as to the utility of, and indiscriminatingly rigorous in the application of economy to, its military establishment. It is impossible for the engineer officer to accompany these detachments, as he should be occupied during the field-season with astronomical work, and with more exact astronomical and barometrical reconnaissances or special surveys.

Such a detachment of men would be constantly occupied in the field from May until October, being employed on short reconnaissances in the neighborhood of their stations in the intervals between the marches of detachments. In the winter they could be kept constantly occupied with office-work, and for the next year in copying township plots and notes at the three surveyor-generals' offices in the department. For the intelligence, skill, and industry required of them, and expense incurred in living during the winter in towns, their compensation should be considerably in excess of the pay and allowances of a private soldier.

To the formation and employment of such a detachment from among the troops of the department four effectual obstacles exist, viz: the prevailing intemperance among the class of enlisted men most intelligent and specially qualified for this work, and who are found in the service solely in consequence of their habits; the natural disinclination of company commanders to recommend and spare their best men for this duty; and the very inadequate compensation of men so detailed, subjecting them to pecuniary disadvantages while rendering the Government more valuable service.

If the exigencies of the engineer service are to continue to prevent the assignment of a detachment of engineer troops to this department for several years past supplied to the neighboring departments of Dakota and of the Missouri, it is very desirable that a detachment of general-service men may be authorized for this work with sufficient and reasonable pay and allowances.

It is strenuously recommended and earnestly hoped that fitting and adequate appropriations may be secured from Congress for the two next fiscal years for the work urgently needed in this department, and described in my last annual report. I respectfully invite attention to, and renew my recommendation therein for, the application as there given

in detail of the sum of $10,000 during the fiscal year immediately ensuing.

For use within the department a special map of Utah and Southeastern Idaho, forming its western portion, is much needed. There is no map of that region suitable for military or common local use, nor has one ever been compiled. Its compilation, which is much needed, has now been delayed three successive years for want of means to secure necessary and important data through the failure in Congress of the appropriation for surveys and reconnaissances in military divisions and departments.

It is designed to apply the $10,000 thus requested for the fiscal year ending June 30, 1878, as follows, viz: To securing the above data from all available sources, embracing, besides the results of mining and other special surveys, the township and railroad surveys from the offices of the surveyors-general and railroad companies in the two Territories; to the office-work of compiling and drawing the map; to the purchase of the astronomical transit and zenith-telescope specified in my last annual report, and of magnetic instruments for use on important special reconnaissances and surveys; and, in addition, as far as it will go, to securing like information from various sources and the offices of the surveyors-general and railroad companies in Nebraska and Wyoming, for a much needed revision of their maps.

A small sum is also needed for providing sun-dials at posts off of the railroad, for repair of instruments and purchase of drawing-materials for the office and for issue in limited quantities to posts. The supply of the latter has been for some time entirely exhausted, causing, with the utter want of means for repairing instruments, much embarrassment.

For the fiscal year ending June 30, 1879, an allotment of $10,000 is also respectfully recommended for application to the completion of the revision of the maps of the department, and to the execution of an important special reconnaissance.

I would respectfully invite attention to the fact that the allotment of $10,000 thus recommended, for each of the two next fiscal years, is desired mainly for the purpose of executing the special work of a thorough revision of the department maps, and of work which has been left undone for want of funds during three years past; and that after the completion of this work the subsequent annual allotments required for current yearly work would be very much smaller, or less than half as large.

About the 1st proximo the field-work, discontinued in September last, will be resumed with the small allotment recently made from the appropriation for surveys for military defenses. First, a reconnaissance will be completed of the routes in the region bounded on the south by the Union Pacific Railroad between Sidney and Medicine Bow Stations, extending northwest to include Fort Fetterman, northeast to Camp Sheridan, and north to the Black Hills, embracing routes to them direct from Forts Fetterman and Laramie and Camp Robinson, and extending north to Deadwood. On completing the routes in that region, and to Fort Hartsuff, and the survey of the military reservation of Fort Laramie, embracing 54 square miles, and of Cantonment Reno, embracing 100 square miles, work will be continued on routes farther west in the department should the season permit.

A map of these reconnaissances and of those made in this region in 1875 and 1876, embracing the reconnaissance with the Big Horn and Yellowstone expedition to Rosebud Creek, will be prepared and submitted during the winter.

My thanks are due to Mr. Frank Lehmer, of the Western Union telegraph-office in this city, for very obligingly and promptly arranging a lone line of telegraph for the exchange of time-signals between Fort Fetterman and Detroit.

In the reduction and computation of field-notes and astronomical observations during the winter, I have received efficient and laborious assistance from Private Henry Kehl, of the general-service detachment, United States Army, at these headquarters.

STATEMENT OF FUNDS.

Expended.

From appropriation for contingencies of the Army, 1877	$125 00
From appropriation for surveys for military defenses, 1876	170 00
Total expended during the fiscal year ending June 30, 1877	295 00
Amount available July 1, 1877, of appropriation for surveys for military defenses	630 00
Amount desired for fiscal year ending June 30, 1879	10,000 00

Very respectfully, your obedient servant,

W. S. STANTON,
Captain of Engineers, U. S. A.,
Chief Engineer Department of the Platte.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

ABSTRACT OF ASTRONOMICAL OBSERVATIONS FOR TIME AND LATITUDE WITH BIG HORN AND YELLOWSTONE EXPEDITION.

For time by equal altitudes of sun's lower limb.

Station, Camp No. 10, at mouth of Prairie Dog Creek, on right bank of Tongue River, Montana.—Date, June 8, 1876.—Observer and computer, W. S. Stanton.

Assumed latitude = 44° 50′ 35″.

Observed double altitudes.		Chronometer times of equal altitudes. A. M. = t.			P. M. = t'.			$t'-t$ = the elapsed time = T.		Equation of equal altitudes = x.	Chronometer fast of mean time at apparent noon by each pair of equal altitudes.	
°	′	h.	m.	s.	h.	m.	s.	h.	m.	s.	m.	s.
111	10	10	34	16	2	51	42.0	4	17	−2.16	44	04.9
	20			49		51	09.2		16	−2.16		04.0
	30		35	20.2		50	37.0		15	−2.14		03.52
	40			54.5			03.4		14	−2.14		03.87
	50		36	27		49	32.3		13	−2.14		04.57
112	00			59.2		48	58.4		12	−2.14		03.72
										Chronometer fast =	44	03.93

Resulting longitude west from Greenwich = 106° 52′ 30″.09.

Time by observation of sun's lower limb.—Method of single altitude.

Station, rendezvous camp at Forks of Goose Creek, Wyoming.—Date, June 13, 1876.—Observer and computer, W. S. Stanton.

Observed double altitudes.		Chronometer times.		
°	′	h.	m.	s.
90	00	3	58	32.3
89	50		59	00.5
	40			30.9
	30			59.5
	20	4	00	28.4
	10			57.0
89	00		1	26.0
88	50			51.4
	40		2	23.3
	30			53.0
	20		3	22.0
	10		3	50.2
88	00		4	19.0
87	50			46.9
87	40		5	16.0
88	50	4	01	54.6

		° ′ ″
Mean observed double altitude	=	88 50 00
Index error, (eccentricity undetermined)	= −	3 05
Double altitude corrected	=	88 46 55
Altitude	=	44 23 27.5
Refraction, (barometer 26.384; detached thermometer 91.55; attached thermometer 94.65)	= −	48.27
True altitude of lower limb	=	44 22 39.23
Semi-diameter	= +	15 46.88
		44 38 26.11
Parallax in altitude	= +	6.20
True altitude = A	=	44 38 32.31
Assumed latitude = L	=	44 49 24.46
A	=	44 38 32.31
North polar distance = Δ	=	66 43 12.92
$L + A + \Delta = 2m$	=	156 11 09.69
m	=	78 05 34 84
$m - A$	=	33 27 02.53

$\log \sin^2 \frac{1}{2} p = \log \dfrac{\cos m \sin m - A}{\cos L \sin \Delta}$	=	19.2419325
$\log \sin \frac{1}{2} p$	=	9.6209662
		° ′ ″
$\frac{1}{2} p$	=	24 41 44.28
p in arc	=	49 23 28.56
		h. m. s.
p in time	=	3 17 33.91
Equation of time	= −	05.13
True mean time of observation	=	3 17 28.78
Chronometer time of observation	=	4 01 54.6
Chronometer fast	=	44 25.82

Time by observation of α Lyræ.—Method of single altitude.

Station, rendezvous camp at Forks of Goose Creek, Wyoming.—Date, June 13, 1876.—Observer and computer, W. S. Stanton.

Observed double altitude.		Chronometer times.		
°	′	h.	m.	s.
112	20	10	44	47.0
	30		45	16.8
	40			45.0
	50		46	13.0
113	00			40.0
	10		47	10.4
	20			38.0
	30		48	06.0
	40			32.0
	50		49	02.9
114	00			32.0
	10			59.0
	20		50	28.0
	30			56.0
	40		51	24.0
113	30	10	48	06.0

			°	′	″
Mean observed double altitude	=		113	30	00.
Index error, (eccentricity not determined)	=	−		3	05.
Double altitude corrected	=		113	26	55.
Altitude	=		56	43	27.5
Refraction, (barometer 26.335; detached thermometer 60.0; attached thermometer 59.8)	=	−			32.95
True altitude of star = A	=		56	42	54.55
Assumed latitude = L	=		44	49	24.46
A	=		56	42	54.55
North polar distance = Δ	=		51	20	01.00
$L + A + \Delta = 2m$	=		152	52	20.01
m	=		76	26	10.00
$m - A$	=		19	43	15.45

$$\log \sin^2 \tfrac{1}{2} p = \log \frac{\cos m \sin (m - A)}{\cos L \sin \Delta} = 19.1550366$$

$$\log \sin \tfrac{1}{2} p = 9.5775183$$

		°	′	″
$\frac{1}{2} p$	=	22	12	40.6
p in arc	=	44	25	21.2
		h.	m.	s.
p in time	=	2	57	41.41
A. R. of star	=	18	32	47.00
Sidereal time of observation	=	15	35	05.59
Sidereal time at mean noon at station	=	5	29	43.42
Sidereal interval past mean noon	=	10	05	22.17
Retardation	=	−	1	39.17
Mean solar time of observation	=	10	03	43.00
Chronometer time of observation	=	10	48	06.00
Chronometer fast	=		44	23.00
Chronometer fast by sun, (west)	=		44	25.82
Chronometer fast by α Lyræ, (east)	=		44	23.00
Chronometer fast, (mean)	=		44	24.41

Resulting longitude west of Greenwich .. 106° 58′ 01″.05

Determination of latitude from observed double altitudes of Polaris.

Station, rendezvous camp at Forks of Goose Creek, Wyoming.—Date, June 13, 1876.—Observer and computer, W. S. Stanton.

		h.	m.	s.
Apparent A. R. of Polaris	=	1	12	044.00
Sidereal time at mean noon at station	=	5	25	46.96
Sidereal interval from mean noon of star's culmination	=	19	46	57.04
Retardation of mean on sidereal time	= −		03	14.45
Mean time of culmination of star	=	19	43	42.59
Chronometer fast of mean time by observations on the sun and α Lyræ this day	=		44	24.41
Chronometer time of culmination of Polaris	=	.8	28	07.00

Index error of sextant, (eccentricity not determined) .... = − 3′ 05″.0
Refraction for mean of observed altitudes, (44° 26′ 43″.12,) (barometer 26.335, attached thermometer 59.8, detached thermometer 60.0) .... = 51″.16
North polar distance of star = Δ = 1° 21′ 14″ = 8474″.
Assumed latitude = 44° 53′ 50″.3. Computation corrected with deduced latitude.

Chronometer time of observation.	Meridian distances. In mean solar time = p.	Meridian distances. In arc = p.	Δ cos p.	+ α (Δ sin p)² tan A.	− β (Δ sin p)² (Δ cos p.)	Observed double altitudes of Polaris out of the meridian.	True altitudes of star as corrected for refraction and errors of instrument = A.	Latitude deduced from each observation = L.
h. m. s.	h. m. s.	° ′ ″	′ ″	″	″	° ′ ″	° ′ ″	° ′ ″
1 11 24.5	7 16 42.5	109 28 26.84	+27 04.09	+50.05	0.27	88 47 30	44 21 21.34	44 49 16.56
16 04.0	12 03.0	108 18 29.62	+25 31.07	+50.08	0.26	50 45	22 58.84	44 49 20.97
19 28.0	08 39.0	107 27 21.24	+24 22.03	+51.33	0.25	53 30	24 21.34	44 49 34.95
31 49.5	6 56 17.5	104 21 21.52	+20 08.49	+53.06	0.21	89 01 40	28 26.34	44 49 28.10
34 17.5	6 53 49.5	103 44 15.44	+19 17.46	+53.37	0.20	03 15	29 13.84	44 49 24.87
Latitude								44 49 25.09

For time by equal altitudes of sun's lower limb.

Station, Fort Fetterman, Wyo.—Date, July 22, 1876.—Observer and computer, W. S. Stanton.

Assumed latitude, 42° 50′ 43″.0.

Observed double altitudes.	Chronometer times of equal altitudes. A. M. = t.	Chronometer times of equal altitudes. P. M. = t′.	t′ − t = the elapsed time = T.	Equation of equal altitudes = x.	Chronometer fast of mean time at apparent noon by each pair of equal altitudes.
° ′	h. m. s.	h. m. s.	h. m.	s.	m. s.
103 00	10 16 59.4	3 11 37.4	4 55	+5.3	38 12.4
10	17 30.4	07.2	54	+5.29	12.79
20	59.4	10 38.0	53	+5.29	12.69
30	18 29.4	07.4	52	+5.28	12.38
40	59.4	9 38.0	51	+5.27	12.67
50	19 29.4	08.0	50	+5.27	12.67
Chronometer fast					38 12.60

Telegraphic time-signals exchanged between United States Lake-Survey Observatory at Detroit and Fort Fetterman, for longitude with local time by sextant.

JULY 22, 1876.

Detroit true mean time when sent from Detroit.	Time by mean solar chronometer No. 926, T. Cotterell & Co., when received at Fort Fetterman.	Differences.
h. m. s.	*h. m. s.*	*m. s.*
9 35 56.11	8 44 23.2	51 32.91
36 06.00	33.2	32.80
15.98	43.3	32.68
26.07	53.2	32.87
35.92	45 03.3	32.62
46.03	13.3	32.73
Mean		51 32.77
10 02 06.05	9 10 33.2	51 32.85
16.10	43.2	32.90
26.02	53.2	32.82
36.09	11 03.3	32.79
46.10	13.3	32.80
Mean		51 32.83

Time by mean solar chronometer, T. Cotterell & Co., No. 926, when sent from Fort Fetterman.	Detroit true mean time when received at Detroit.	Differences.
h. m. s.	*h. m. s.*	*m. s.*
8 53 00.0	9 44 32.98	51 32.98
10.0	42.98	32.98
20.0	53.01	33.01
30.0	45 02.98	32.98
40.0	13.09	33.09
50.0	23.05	33.05
54 00.0	33.04	33.04
Mean		51 33.02

	h.	*m.*	*s.*
Mean of first set		51	32.77
Mean of second set			32.83
Mean of third set			33.02
Chronometer slow of Detroit mean solar time		51	32.87
Chronometer fast of Fort Fetterman mean solar time		38	12.60
Fort Fetterman west of Detroit	1	29	45.47
Detroit west of Greenwich	5	32	12.24
Longitude of Fort Fetterman west from Greenwich	7	01	57.71
	°	′	″
	105	29	25.65

A storm prevailing, two sets of signals from Detroit were not received at Fort Fetterman, and confidence was impaired in the above result. Signals were therefore exchanged again July 28.

For time by equal altitudes of sun's lower limb.

Station, Fort Fetterman, Wyo.—Date, July 28, 1876.—Observer and computer, W. S. Stanton.

Observed double altitudes.	Chronometer-times of equal altitudes. A. M. = t.			Chronometer-times of equal altitudes. P. M. = t'.			t' − t = the elapsed time = T.		Equation of equal altitudes = x.	Chronometer fast of mean time at apparent noon by each pair of equal altitudes.	
° ′	h.	m.	s.	h.	m.	s.	h.	m.	s.	m.	s.
93 00	9	53	03.2	3	35	34.0	5	42	+6.71	38	12.69
10			32.4			04.9	5	42	+6.71		12.74
20		54	01.5		34	36.4	5	40	+6.69		13.02
30			31.0			07.0	5	40	+6.69		13.07
40		55	00.5		33	37.0	5	38	+6.68		12.81
50			29.0			08.0	5	38	+6.68		12.56
94 00			58.0		32	39.2	5	36	+6.66		12.64
10		56	28.0			10.0	5	36	+6.66		13.04
20			57.4		31	40.7	5	36	+6.66		13.09
40		57	55.8		30	42.2	5	33	+6.64		13.02
50		58	24.0			14.0	5	31	+6.62		13.00
Chronometer fast										38	12.88

For time by equal altitude of sun's lower limb.

Station, Fort Fetterman, Wyo.—Date, July 29, 1876.—Observer and computer, W. S. Stanton.

Observed double altitudes.	Chronometer-times of equal altitudes. A. M. = t.			Chronometer-times of equal altitudes. P. M. = t'.			t' − t = the elapsed time = T.		Equation of equal altitudes = x.	Chronometer fast of mean time at apparent noon by each pair of equal altitudes.	
° ′	h.	m.	s.	h.	m.	s.	h.	m.	s.	m.	s.
99 40	10	13	46.0	3	14	46.0	5	00	+6.55	38	11.87
50		14	16.0			15.3	5	00	+6.55		11.52
100 00			46.2		13	45.0	5	00	+6.55		11.47
10		15	17.0			15.0	4	57	+6.52		11.84
20			47.4		12	45.4	4	57	+6.52		12.24
30		16	18.0			14.0	4	57	+6.52		11.84
40			48.2		11	44.5	4	54	+6.50		12.17
50		17	18.3			14.3	4	54	+6.50		12.12
101 00		17	49.8		10	43.4	4	54	+6.50		12.42
10		18	19.0			14.0	4	51	+6.48		12.30
20			49.7		9	41.3	4	51	+6.48		11.30
30		19	21.0			11.0	4	51	+6.48		11.80
40			51.3		8	41.0	4	48	+6.46		11.93
50		20	23.0			09.4	4	48	+6.46		11.98
102 00			53.2		7	39.3	4	48	+6.46		12.03
Chronometer fast										38	11.92

	m.	s.
Chronometer fast at apparent noon July 28	38	12.88
Chronometer fast at apparent noon July 29	38	11.92
Chronometer fast at exchange of signals, July 28	38	12.40

Telegraphic time-signals exchanged between United States Lake-Survey Observatory at Detroit and Fort Fetterman, for longitude with local time by sextant.

Time by mean solar chronometer No. 926, T. Cotterell & Co., when sent from Fort Fetterman.	True mean time when received at Detroit.	Differences.
h. m. s.	h. m. s.	m. s.
8 30 20	9 21 51.18	51 31.18
30	22 01.26	31.26
40	11.65	31.65
50	21.17	31.17
31 00	31.00	31.00
Mean		51 31.25
8 58 40	9 50 11.32	51 31.32
50	21.28	31.28
59 00	31.25	31.25
10	41.16	31.16
20	51.26	31.26
30	51 01.24	31.24
40	11.66	31.66
50	21.23	31.23
9 00 00	31.21	31.21
Mean		51 31.29

True mean time when sent from Detroit.	Time by chronometer No. 926 when received at Fort Fetterman.	Differences.
h. m. s.	h. m. s.	m. s.
9 35 55.56	8 44 24.3	51 31.26
36 05.51	34.0	31.51
15.59	44.3	31.29
25.58	54.3	31.28
35.45	45 04.3	31.15
45.36	14.3	31.06
Mean		51 31.26
9 39 55.63	8 48 24.3	51 31.33
40 05.56	34.6	30.96
15.61	44.3	31.31
25.56	54.4	31.16
35.56	49 04.3	31.26
45.54	14.3	31.24
Mean		51 31.21
9 45 55.57	8 54 24.3	51 31.27
46 05.60	34.3	31.30
15.62	44.4	31.22
25.44	54.4	31.04
35.48	55 04.3	31.18
45.49	14.3	31.19
Mean		51 31.20

	h.	m.	s.
Mean of first set		51	31.25
Mean of second set		51	31.29
Mean of third set		51	31.26
Mean of fourth set		51	31.21
Mean of fifth set		51	31.20
Chronometer slow of Detroit mean solar time		51	31.24
Chronometer fast of Fort Fetterman mean solar time		38	12.40
Fort Fetterman west of Detroit	1	29	43.64
Detroit west of Greenwich	5	32	12.[illegible]
Longitude of Fort Fetterman west from Greenwich	7	01	55.[illegible]
	°	′	″
	105	28	57.2
Longitude of Fort Fetterman, determined July 22	105	29	25.65
Longitude of Fort Fetterman, determined July 28	105	28	58.[illegible]
Mean result	103	29	11.[illegible]

Determination of latitude from observed double altitudes of Polaris.

Station, Fort Fetterman, Wyo.—Date, July 20, 1876.—Observer and computer, W. S. Stanton.

		h.	m.	s.
Apparent A. R. of Polaris		1	13	18.92
Sidereal time at mean noon at station	=	7	55	31.10
Sidereal interval from mean noon of star's culmination		17	17	47.82
Retardation of mean on sidereal time	= −		2	49.90
Mean time of culmination of star		5	14	57.92
Chronometer fast of mean time at station	=		38	10.14
Chronometer-time of culmination of Polaris	=	5	53	08.06
Index-error of sextant	= −		2′	40″
Refraction, (barometer 25.25, attached thermometer 73, detached thermometer 72.8)	=			50″
North-polar distance of star = Δ = 1° 21′ 12″.3	=			4872″.3
Assumed latitude	=	42°	50′	43″

Chronometer-time of observation.	Meridian distances. In mean solar time = p.	Meridian distances. In arc = p.	Δ cos p.	+ α (Δ sin p)² tan A.	− β (Δ sin p)² (Δ cos p.)
h. m. s.	h. m. s.	° ′ ″	′ ″	″	″
1 7 57.0	4 45 11.06	71 29 28.63	25 50.43	48.92	0.26
9 26.0	43 42.06	07 09.98	26 20.43	48.72	0.26
10 54.9	42 13.16	70 41 52.72	26 50.35	48.51	0.27

Observed double altitude of Polaris out of the meridian.	True altitudes of star as corrected for refraction and errors of instrument = A.	Latitude deduced from each observation = L.
° ′ ″	° ′ ″	° ′ ″
86 35 00	43 15 20	42 50 18.23
36 00	50	42 50 18.03
37 00	16 20	42 50 17.89
Latitude		42 50 18.05

Latitude from circummeridian altitudes of Altair.

Station, Fort Fetterman, Wyo.—Date, July 20, 1876.—Observer and computer, W. S Stanton.

	h.	m.	s.
Apparent A. R. of Altair	19	44	47.[illegible]
Sidereal time at mean noon at station	7	55	31.1[illegible]
Sidereal interval from mean noon of star's culmination	11	49	15.9[illegible]
Retardation of mean on sidereal time		1	56.3[illegible]
Mean time of culmination of star	11	47	19.7[illegible]
Chronometer fast of mean time at station		38	10.14
Chronometer-time of culmination of star	12	25	29.92

Index-error of sextant = — 2' 40''
Refraction, (barometer 25.25, detached thermometer 72.8, attached thermometer 73.0) = 32''.14
Assumed latitude = 42° 50' 43''

Chronometer-time of observations.		Meridian distances = p in sidereal time.	$\frac{2\sin^2\frac{1}{2}p}{\sin 1''}=k.$	$\frac{\cos l \cos D}{\cos a}.$	Reduction to the meridian (in arc) = x.	Observed double circummeridian altitudes of star.	True circummeridian altitude of star as corrected for errors of instrument and refraction.	True meridian altitudes deduced = (a + x) = A.	Latitude deduced from each observation L = (90° + D — A).
h. m. s.		m. s.	''		' ''	° ' ''	° ' ''	° ' ''	° ' ''
12 15 22.0	Chronometer-time of culmination of star = 12h 25m 29s.92.	10 9.6	202.62	Constant multiplier, 1.28656.	4 20.7	111 19 00	55 37 37.86	55 41 58.56	42 50 35.84
16 06.1		9 25.4	174.34		3 44.3	20 00	38 07.86	52.16	42 50 42.34
40.0		8 51.4	154.04		3 18.2	21 00	37.86	56.06	42 50 38.34
17 24.8		06.4	129.00		2 46.0	22 00	39 07.86	53.86	42 50 40.54
57.0		7 34.2	112.50		2 24.7	23 00	37.86	42 02.56	42 50 31.54
18 55.0		6 36.0	85.50		1 50.0	24 00	40 07.86	41 57 86	42 50 36.54
19 38.0		13.0	75.90		1 37.6	25 00	37.86	42 15.46	42 50 19.34
20 32.0		4 58.7	48.68		1 02.6	26 00	41 07.86	10.46	42 50 23.34
22 37.0		3 53.6	29.78		0 38.31	27 00	37.86	· 16.17	42 50 18.23
24 13.0		1 17.1	3.24		0 04.27	27 30	52.86	41 57.13	42 50 37.[illegible]
25 40.0		0 12.0	0.08		0 00.10	27 30	52.86	52.96	42 50 41.44
27 00.0		1 30.3	4.45		0 05.73	27 30	52.86	58.59	42 50 35.81
28 55.0		3 25.6	23.02		0 29.62	26 30	22.86	52.48	42 50 41.9[illegible]
33 55.0		8 26.5	139.90		3 00.00	21 40	38 57.86	57.86	42 50 36.54
35 15.0		9 46.7	187.72		4 01.51	19 40	37 57.86	59.37	42 50 35.6[illegible]
									42 50 34.3

Latitude from circummeridian altitude of Altair.

Station, Fort Fetterman, Wyo.—Date, July 26, 1876.—Observer and computer, W. S. Stanton.

	h.	m.	s.
Apparent A. R. of Altair	19	44	47.12
Sidereal time at mean noon at station	8	19	14.46
Sidereal interval from mean noon of stars — culmination	11	25	32.66
Retardation of mean on sidereal time		1	52.31
Mean time of culmination of star	11	23	40.35
Chronometer fast of mean time at station		38	13.84
Chronometer-time of culmination of star	12	01	54.19

		′	″
Index error of sextant	= +	2	32.5
Refraction, (barometer 25.199, attached thermometer 67.25, detatched thermometer 68.25)	=		32.402
Assumed latitude	=		42° 50′ 52″

Chronometer-time of observation.		Meridian distances = p in sidereal time.	$\frac{2 \sin^2 \frac{1}{2} p}{\sin 1''} = k$	$\frac{\cos l \cos D}{\cos a}$	Reduction to the meridian (in arc) = x.	Observed double circummeridian altitudes of star.	True circummeridian altitude of star as corrected for errors of instrument and refraction.	True meridian altitudes deduced = $(a + x)$ = A.	Latitude deduced from each observation = L = $(90° + D - A)$.
h. m. s.		m. s.	″		′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
11 49 40.0	Chronometer-time of culmination of star, 12h 01m 54s.19.	12 16.2	295.56	Constant multiplier, 1.28644.	6 20.1	111 10 00	55 35 43.85	55 42 04.00	42 50 31.6
51 22.0		10 33.9	219.13		4 41.8	13 00	37 13.85	41 55.7	42 50 39.9
52 25.0		9 30.7	177.62		3 48.4	15 00	38 13.85	42 02.2	42 50 33.4
53 31.4		8 24.2	138.62		2 58.2	17 00	39 13.85	42 12.0	42 50 23.6
54 16.9		7 38.5	114.60		2 27.4	18 00	39 43.85	42 11.2	42 50 24.4
55 00.0		6 55.3	94.05		2 01.0	19 00	40 13.85	42 14.8	42 50 20.8
56 14.6		5 40.5	63.20		1 21.3	20 00	40 43.85	42 05.2	42 50 30.4
57 13.4		4 41.6	43.28		0 55.7	21 00	41 13.85	42 09.6	42 50 26.0
58 01.0		3 53.8	29.84		0 38.3	21 30	41 28.85	42 07.2	42 50 28.4
58 59.8		2 54.9	16.68		0 21.5	22 00	41 43.85	42 05.4	42 50 30.2
59 41.0		2 13.6	9.72		0 12.5	22 00	41 43.85	41 56.4	42 50 39.2
12 01 42.0		0 12.2	0.08		0 00.1	22 30	41 58.85	41 59.0	42 50 36.6
04 47.0		2 53.3	16.36		0 21.1	21 30	41 28.85	41 50.0	42 50 45.6
06 34.4		4 41.0	43.10		0 55.4	20 40	41 03.85	41 59.3	42 50 36.3
08 36.3		6 43.2	88.68		1 54.1	18 40	40 03.85	41 58.0	42 50 37.6
11 03.0		9 10.3	165.18		3 32.4	15 30	38 28.85	42 01.3	42 50 34.3
12 49.0		10 56.6	235.12		5 02.3	12 20	36 53.85	41 56.2	42 50 39.4
15 06.0		13 14.0	343.70		7 22.0	07 30	34 28.85	41 50.9	42 50 44.7
16 28.0		14 36.2	418.60		8 58.3	04 30	32 58.85	41 57.2	42 50 38.4
18 15.5		16 24.0	527.90		11 18.9	111 00 00	30 43.85	42 02.8	42 50 32.8
19 59.8		18 08.6	646.02		13 50.8	110 55 00	28 13.85	42 04.7	42 50 30.9
									42 50 33.55

Determination of latitude from observed double altitudes of Polaris.

Station, Fort Fetterman, Wyo.—Date, July 27, 1876.—Observer and computer, W. S. Stanton.

	h.	m.	s.
Apparent A. R. of Polaris	1	13	24.7
Sidereal time at mean noon at station	8	23	11.0
Sidereal interval from mean noon of stars—culmination	16	50	13.7
Retardation of mean on sidereal time		2	45.5
Mean time of culmination of star	16	47	28.2
Chronometer fast of mean time at station		38	12.75
Chronometer-time of culmination of Polaris	5	25	40.95

Index-error of sextant = +1′ 02″.5
Refraction, (barometer 25.107, attached thermometer 72.8, detached thermometer, 73.4) = 51″.2
North polar distance of star = Δ = 1° 21′ 11″.3 = 4871″.3
Assumed latitude = 42° 50′ [illegible]

Chronometer-time of observations.	Meridian distances. In mean solar time = p.	Meridian distances. In arc = p.	$\Delta \cos p$.	$+ a\,(\Delta \sin p)^2 \tan A$	$- \beta\,(\Delta \sin p)^2\,(\Delta \cos p.)$
h. m. s.	h. m. s.	° ′ ″	′ ″	″	″
10 01 48.0	7 23 52.95	111 16 28.03	+29 27.48	45.5	0.29
04 50.0	20 50.95	110 30 50.55	+28 27.09	46.0	0.[illegible]
10 25.0	15 15.95	109 06 51.80	+26 35.13	46.86	0.[illegible]
15 43.9	09 57.05	107 46 55.20	+24 47.67	47.65	0.[illegible]
19 39.9	06 01.05	106 47 45.51	+23 27.64	48.20	0.24

Observed double altitude of Polaris out of the meridian.	True altitudes of star, as corrected for refraction and errors of instrument = A.	Latitude deduced from each observation = L.
° ′ ″	° ′ ″	° ′ ″
84 40 00.0	42 20 00.05	42 50 13.32
42 50.0	21 05.05	42 50 18.42
46 40.0	23 00.05	42 50 22.30
50 10.0	24 45.05	42 50 20.62
52 50.0	26 05.05	42 50 21.13
Latitude		42 50 19.158

Latitude of Fort Fetterman.

	°	′	″
By Polaris, July 20	42	50	18.05
By Altair, July 20	42	50	34.30
Mean by north and south stars, July 20	42	50	26.17
By Altair, July 26	42	50	33.55
By Polaris, July 27	42	50	19.16
Mean by north and south stars, July 26 and 27	42	50	26.35
By north and south stars, July 20	42	50	26.17
By north and south stars, July 26 and 27	42	50	26.35
Latitude adopted	42	50	26.26

For time by equal altitudes of sun's lower limb.

Station, Camp Sheridan, Nebr.—Date, August 24, 1876.—Observer and computer, W. S. Stanton.

Observed double altitudes.	Chronometer times of equal altitudes. A. M. = t.	Chronometer times of equal altitudes. P. M. = t'.	$t'-t$=the elapsed time =T.	Equation of equal altitudes=x.	Chronometer fast of mean time at apparent noon by each pair of equal altitudes.
° ′	h. m. s.	h. m. s.	h. m.	s.	m. s.
97 40	10 31 23.9	2 25 37.1	3 54	+10.48	26 41.84
50	32 01.0	25 00.0	3 54	+10.48	41.84
98 00	39.4	24 21.2	3 51	+10.46	41.62
10	33 16.9	23 43.3	3 51	+10.46	41.42
20	53.5	07.3	3 49	+10.45	41.71
30	34 31.9	22 28.9	3 49	+10.45	41.71
40	35 09.4	21 50.0	3 46	+10.43	40.99
50	48.3	12.0	3 46	+10.43	41.44
99 00	36 26.0	20 33.9	3 43	+10.40	41.21
10	37 03.9	19 56.0	3 43	+10.40	41.21
20	41.9	18.2	3 41	+10.39	41.30
30	38 21.2	18 39.2	3 41	+10.39	41.45
40	59.0	01.0	3 39	+10.38	41.24
50	39 39.3	17 20.4	3 39	+10.38	41.09
Chronometer fast					26 41.43

Assumed latitude=42° 50′ 43″.

Longitudes determined with sextant and chronometer.

	h. m. s.	° ′ ″
Camp on Tongue River at the mouth of Prairie Dog Creek, Montana	7 07 30.06=	106 52 30.9
Camp at Forks of Goose Creek, Wyoming	7 07 52.70=	106 58 01.05
Camp Cloud Peak, on North Fork of Goose Creek, Wyoming	7 08 02.31=	107 00 34.65
Camp on Crazy Woman's Fork of Powder River	7 05 59.80=	106 29 57.0
Camp on right bank of Powder River, opposite old Fort Reno	7 04 49.88=	106 12 28.2
Fort Fetterman	7 01 56.79=	105 29 11.85
Camp Sheridan	6 50 35.11=	102 38 46.7

Latitudes with sextant.

	° ′ ″
Camp at Forks of Goose Creek, Wyoming	44 49 25.09 by Polaris.
Fort Fetterman	42 50 26.26 by north and south stars.
Camp Sheridan	42 51 09.56 by Polaris.

The foregoing astronomical determinations with sextant No. 1601 by Stackpole & Brother, and mean solar chronometer No. 926, T. Cotterell & Co.

APPENDIX R R.

ANNUAL REPORT OF LIEUTENANT E. H. RUFFNER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF THE MISSOURI.

HEADQUARTERS DEPARTMENT OF THE MISSOURI,
OFFICE OF THE CHIEF ENGINEER,
Fort Leavenworth, Kans., July 16, 1877.

SIR: I have the honor to submit the following as my annual report for the year ending June 30, 1877:

Inasmuch as there was no appropriation available for the uses of the office during the year, no skilled labor was employed and no operations were conducted. An effort was made to finish work on hand at the beginning of the year, and to do something with new matter accumulated during the same time. The notes of the survey of the headwaters of the Red River of Texas have been worked on, and a report is made of the same and appended herewith. My principal trouble has been the loss of a professional draughtman. Sergeant G. A. Lichtenberg, Company D, Battalion of Engineers, has been on duty in the office throughout the year, and has made good progress and has been of more than ordinary service in the preparation and tracing of maps of various sorts. Lieut. C. A. H. McCauley, Third Artillery, and Lieut. T. M. Woodruff, Fifth Infantry, have been on duty in the office at different periods, and have been engaged in the preparation of the Red River report. Private H. Hartmann, Company C, Fourth Cavalry, was also engaged a part of the time as a draughtsman.

I have been employed myself in preparing the notes for platting and in working up the report, especially the meteorological notes and the water-color sketches.

No maps have been published by this office since the Indian Territory map in 1875, and none have been submitted for publication. Of the general work done in the department, the usual reports of scouts and marches are made, and although the movements of troops have not been extensive, still a fair number of miles is recorded. During the calendar year 1876 a total of 4,909 miles is reported; as compared with 5,341 during the preceding year. The members of the engineer detachment have been employed as usual in recording routes of march, in instructing enlisted men in the methods of topographical work, and at the engineer offices of the department. The value of the services of these men has been again shown, and the department commander has recently called my attention to his appreciation of their work, and has directed me to make application for such additional men as are needed to render the detachment efficient. The loss by suicide of Corporal William Holland, Company D, Battalion of Engineers, while suffering under an attack of acute melancholia, has been a serious one, and ex-

piration of term of service has reduced the detachment to three members at present.

During the summer of 1876, a chain measurement of Quartermasters' Freight Route No. 1, from Fort Leavenworth, Kans., to Fort Laramie, (now Wyoming Territory,) was done at the request of the Department of Justice, and the officer in charge, Lieut. C. C. Hewitt, Nineteenth Infantry, made the report as directed. This was unfortunately lost in the mails, and Lieutenant Hewitt prepared a duplicate report in this office which was copied and the copy filed here. The preparation of the map, which was platted on four sheets of double elephant paper, and then a reduced copy made for retention, occupied several weeks of the time of the draughtsman.

The reservation of Fort Stanton, N. Mex., was redescribed and published in general orders from these headquarters during the year, in accordance with the resurvey and the reduction as prescribed by act of Congress.

The preliminary papers for the declaration of a military reservation at Fort Elliott, Texas, have passed through this office, and a survey was made of the lines of the proposed reservation by Sergeant F. W. Maier, Company D, Battalion of Engineers.

A plat and a description of proposed reservations at Fort Reno, Indian Territory, for timber and for the general use of the post, have been prepared in this office, and are now under consideration by the proper authorities.

During my temporary absence on duty at the Centennial Exhibition at Philadelphia, from October 11 to December 30, 1876, the office was in charge of Lieut. T. M. Woodruff, Fifth Infantry. Lieut. C. A. H. McCauley, Third Artillery, now on duty in this office, is at present engaged in a prolonged reconnaissance through the mining regions of Southern Colorado, with orders to report exactly the number of persons at present engaged in these mines, and to examine the location and condition of all roads to these regions. He will also report in especial as to the capabilities of certain points for use as the location of a military post for the better protection of the settlers. It is not expected that Lieutenant McCauley will do any surveying, but he will make use of the maps furnished him by Lieut. G. M. Wheeler, through the Chief of Engineers, and locate his routes thereon. He will be engaged upon this work during the entire summer.

The following maps have been issued from the office during the past year:

Map of Indian Territory, 4 sheets	32
United States military divisions and departments, Engineer Bureau	3
Kansas, Indian Territory, and Texas, Engineer Bureau	1
Ute reconnaissance, 1873	2
Department of the Missouri, sheet No. 2	6
Department of the Missouri, sheet No. 4	6
New Mexico, Morrison, 1875	64
Miscellaneous maps	8
Miscellaneous tracings made and issued	11
Total	133

The sheets Nos. 2 and 4 of the Department of the Missouri maps are now out of print and the editions exhausted, and but few copies of the Ute reconnaissance maps remain.

An unexpended balance of the appropriation for surveys for military defenses having been again made available by Congress, an allotment has been made to this office for the present fiscal year of $1,200, and it

is hoped that an appropriation for the coming year will be made, so as to render the office again of the service that it has been in past years. Nothing especial is contemplated for immediate field-work, though, as shown above, it is very desirable that exhausted editions of useful maps should be replaced by new and improved issues, as was the original intention in the first preparation and printing, and the exigencies of the military service make field-work liable at any moment. Attention is invited to the accompanying report on the survey of the Red River.

Very respectfully, your obedient servant,

E. H. RUFFNER,
First Lieutenant of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

SURVEY OF THE HEADWATERS OF RED RIVER, TEXAS.

In accordance with verbal instructions from the department commander, and with a schedule of written instructions prepared by myself and approved by General Pope, I left this post on April 25, 1876, to make a prismatic-compass and theodolite and stadia-line survey of the head of permanent water of the Red River of Texas. The party took wagon-transportation from Dodge City to Camp Supply, and having obtained the necessary transportation at the latter point for the whole trip, went on to Fort Elliott, Texas. Here a suitable cavalry and infantry escort was obtained to do the necessary labor and give a proper protection during the work. Fort Elliott was reached May 6. The preliminaries of prepaation were made and some work necessary to secure a good start was done, so that the party was able to leave on the 11th. The plan of work was as follows: The escort and train proceeded from camp to camp by the most direct line or trail, and this route was recorded by Sergeant G. A. Lichtenberg, Company D, Engineers, by means of the usual prismatic-compass and odometer readings. The start was made as early in the morning as it was light enough to read the instruments by, and except in case of an unusually long march, the new camp was reached by noon.

The stadia-line was run by myself. The meridian was determined by an astronomical portable transit at each camp, when practicable, and from the line so established the azimuth of the course was taken by a theodolite, and was preserved throughout the march by back sights from each station to the preceding one. The distances were obtained by use of the cross hairs of the telescope bisecting the two shields of an ordinary leveling-rod, which were separated, as directed by signal from the person at the theodolite, until the interval between the shields marked the angular distance of the two parallel horizontal wires of the reticle. The two readings of the shields were recorded, and the difference gave this interval in feet to the decimal of thousandths. The coefficient of distance was obtained by carefully chaining off on the ground a thousand feet, and then by repeated measurements getting the angular distance as given by the difference between the readings. The value in decimals of a foot for the stadia-interval was thus given for 1 foot, 100 feet, &c., on the ground in horizontal distance.

This coefficient was afterward tested by remeasurements at different times. The method is not intended for the most accurate of work, but under the circumstances the results were good. It was found that or-

dinary spider-lines were apt to sag in the early morning when the air was damp, and when the "mirage" became excessive in the heat of the day, difficulty was found in getting an exact bisection of the shields from their "dancing." The rate of work depended upon the facility with which the arrangements were carried out. The theodolite was carried on horseback, at a walk, the points of the tripod being inserted at the stirrup into a carbine-sling, as a guidon would be carried on the other side. It was found best to use two stadia-rods, alternately, as much depended upon judicious selection of stations. When the best conditions prevailed, between 2½ and 3 miles an hour could be run upon the open prairie. As high as 22 miles were made during a day's march. The distances were best maintained at about 1,500 feet, though one particular advantage of the system was well displayed in the crossing of cañons and wide valleys where chaining would have been difficult or impossible. Indeed, the best results of the method are found in rough country. The records when reduced were platted by latitudes and departures, and the error in closing from Mulberry Creek Camp to return to the same was about 1 per cent. Errors of azimuth were detected upon reaching the following camp and establishing the meridian again; and after a due allowance for convergence the remaining errors were not found to be material. The details of topography were recorded by the recorders of the stadia-rods, as well as on the prismatic-compass line, which latter was the longer, as the stadia-line went directly across obstacles which caused the wagons to make a detour.

Lieut. C. A. H. McCauley, Third Artillery, and Lieut. T. M. Woodruff, Fifth Infantry, assisted in the selection of the stadia-line and its stations, and enlisted men were soon taught to read the verniers of the level-rods correctly and kept good records. When passing through country where it seemed advisable, Ado Hunnius, draughtsman in this office, made topographical sketches at suitable points to catch the shape of the land. At other times he assisted on the stadia-line and Lieutenant McCauley took the necessary sketches.

Sergeant G. A. Lichtenberg, Company D, Battalion of Engineers, in addition to his other work, kept the meteorological record, and the manner in which the observations were taken will be found specified in the meteorological report annexed. During the march my own attention was given entirely to the stadia-line, but during our stay in camp I endeavored to take such geological notes as I could, and a brief *résumé* will be found under that head.

At night I established the meridian, when practicable, and for this and other reasons I carried with me a Würdeman portable transit, and as an experiment a frame-work which could be sunk in the earth and after being made solid by ramming the soil back again around the legs, could be used as the pier for the instrument. It was my intention to attempt to determine the latitude by the prime vertical and the longitude by lunar culminations, in addition to using the transit for meridian-lines and for time. I found, however, that I did not stay long enough in any one place, and at this writing I am disappointed in the results. The latitude of two points was attempted. One may be considered well determined. Observations for lunar culminations were made at two points and the reductions are not satisfactory to me; whether from lack of skill in the reduction or from inherent fault of the observations themselves, I am unable to state. Possibly I expected to do too much myself, and I should have succeeded better by taking more time and being more at ease.

Lieut. C. A. H. McCauley, Third Artillery, joined the party as a vol-

unteer and gave me great assistance in everything where intelligence, industry, and enthusiasm were expected. Although in bad health, he was always willing, cheerful, and efficient. He made a collection illustrating the ornithology of the region, and brought back an interesting series of bird skins, nests, and eggs. Besides this work, he rendered, as stated above, services on the stadia-line and in taking sketches of the topography. Upon returning to this point, he rendered me a full and interesting report on the ornithology of the region. He afterward furnished to the survey conducted by Dr. Hayden a copy of his report without mentioning the matter to me and requested its publication. This was done, and the report will now be found among the publications of that survey, to which it does not in any manner belong.

Lieut. Thomas M. Woodruff, Fifth Infantry, was engaged in his leisure moments in making such a collection of botanical and other natural-history specimens as his facilities allowed him to do, and his unwearied attention to this and his faithfulness in executing all duties intrusted to him are worthy of special mention. His reports on the specific duties performed by him will be found appended.

Lieut. F. D. Baldwin, Fifth Infantry, was in command of the escort, which consisted of eighteen enlisted men of the Fourth Cavalry and fourteen of the Nineteenth Infantry, and by his activity, energy, and attention to details caused the utmost smoothness to exist in all the work, and the surveying parties were always found ready for work, and uninterrupted by any annoyance or drawbacks.

Acting Asst. Surg. W. E. Sabin completed the *personnel* of the party.

The first camp was made at Cottonwood Creek, 12½ miles west from Fort Elliott, and a delay of a day enabled the party and escort to be suitably organized for work. The next day's march was 9½ miles west, to Big Springs, on the North Fork of Red River. Fort Elliott is beautifully situated on a high level between two of the heads of the Sweetwater, a branch of the North Fork. An abundance of fine fresh water and a heavy grove of cottonwood led to its selection. Not far off are fine groves on several of the adjacent streams, which have been heavily drawn on for the construction of the post and for the necessary fuel. On the north and west the edges of the upper level of the Staked Plains appear, and outlying buttes similarly capped with the hard white limestone, which preserves the upper layers and; until washed away, all that may be covered by it; are met with from the Canadian, down. Rolling country, well grassed in the spring, extends to the east and south, and the lower levels and valleys have as fine grazing as need be wished. The advent of the new post and the removal of the Indians have brought many settlers into the vicinity, and milk and butter and eggs are sold in ranches where three years ago a single company of cavalry was not too great an escort. Cottonwood Creek runs into the North Fork some 8 miles down below our crossing. A ranch was found on the creek, and growing corn. A particularly large grove of cottonwoods fills the bottom, and was the subject of the first water-color sketch submitted with this report. The country of the North Fork is much the same as the rest described, except that more sand is found than at any other point since leaving the Canadian.

Upon leaving the Big Springs we entered directly upon the general surface of the Staked Plains. From this point to the camp on McClellan Creek, and (excepting the slightly rolling vicinage of the Salt Fork) from that point until we came down the mesa into the Tule Cañon, we were on the upper level.

A description of a monotony may be tiresome and monotonous, but

the reality need not be. The long steady view or the gentle swell, and long, long wave of the quiet parched plain, has a strange fascination, and the slightest break to its vacuity has an alarming attraction. A withered "soap-weed" may be a forest; its dead last year's stalk of bloom may be a painted warrior. The wide shallow ponds may have water in them or not, according as pleases the sprites of the desert. The white swells of the canvas wagon-covers or tents may loom up and waver as though a mountain of snow in the distance, and the dancing, quivering heat and flame between you and them may be those of adventurous souls who have tried to reach the cool breath. The rabbit or the startled antelope may be the sudden vision that all eyes see, and the bleaching bones may seem to be herds of antelope, deer, elk, or what not animal, known or unknown. The first low swell ahead of you a hundred yards may magnify its short dried herbs to a distant forest in the misty morning, and the cliffs of the breaks 8 miles away may really be twice that.

The short withered grass, the famed buffalo-grass, grows everywhere, and the sad signs of many bleaching carcasses, and later in our journey the occasional tent and wagon of the buffalo-hunter, and the scattered bands, and their many halt, lame, and blind, show that the buffalo have no longer here a home.

As there had been little or no rain during the early spring, and as we had very little during our trip, the ponds or drain-basins, that are everywhere on the plains, had no water in them, though they were evidently wet during some part of each year. The hard, firm road made traveling easy everywhere for man and beast.

The point at which we crossed McClellan Creek was near the head of its water, and we had passed around the head of its north fork entirely. The creek was at that place in a cañon, some 100 or more feet below the general level. Upon our return we first struck the creek some 5 miles below this point, and here we met the finest grove of cottonwoods encountered on the trip. It was three or four miles long, and the valley was very pretty, with rolling hills, and a bottom in places a quarter of a mile wide.

The Salt Fork and Mulberry Creek were both pretty much alike, with a scant supply of good water, a few trees, and rolling ground at the upper breaks. Mulberry Creek, however, cañons soon and very deeply.

The next march brought us to the main cañon of Red River, and a gorgeous sight the first view of it was. Down one of its side cañons we looked on the strange scene. Cliffs of brilliant red sandstone were the main walls of the cañon, and the cap-stone the usual white limestone of the country. Lower down in the valley the sandstones are seen to be supplanted by clays and the gypseous mixtures of lime and sandstone and clays; the whole, so washed and twisted and shapen as to marvel the eye with its intricacy and daze it with its brilliancy, formed a wild and enchanting scene. So vivid are the colors that I have in vain tried to secure from one who has not seen such, the recognition due some of my copies of the tints; nay, though I have specimens of the colored clays and stones placed beneath the pictures themselves, they seem not to acknowledge them truthful.

Our camp, occupied near the head of the cañon, was called a permanent camp, and I submit a view of the cañon here. At this point I halted the party, and devoted a week to running a line to the head of water on the Palo Duro, the northern of the two streams which form the Red River. It had been said that this stream was many miles in length, but I traced it to its head with no trouble and then crossed south to

the other stream, called the Tierra Blanca. The route made by Col. J. I. Gregg, of the Eighth Cavalry, in 1872, was down this stream, and as he had been to the head of water there, it was not necessary to go farther. The heads of these streams and of the Tule, which was afterward ascended to a similar point, presented at these times a very lovely picture. We were above the cañons, and the low rolling banks of the courses were not enough to call hills. The fringe of brushes and low trees near the water opened into one or two groves on the Palo Duro, and the grass and foliage bore its brightest spring-green. The birds swarmed in the untouched wilderness and sang and twittered without ceasing. Antelope in great quantity and an occasional herd of mustangs gave life to the scene. The upper course of the Tierra Blanca lay through marshes and low, flat meadows, and the whole evidently formed a choice grazing-ground for a limited number of suitable animals. Doubtless we saw it at its best, but it must always be of value as a stock-range.

I have endeavored to represent accurately and without any exaggeration the vivid tints of this region in my two sketches on the Palo Duro and the Tierra Blanca. The water of the first stream contained small catfish within 2 miles of the head of water. The upper course of the Tule has an exactly similar country to this, and I went to the head of water there also.

During my trip up the Palo Duro, Lieutenant Woodruff ran a line to the Canadian, as described by him, and of which the two sheets 14 and 15 give the result. This was done to connect the work with the various surveys up that river.

At the permanent camp I took a sketch, which exhibits the character of the cañon there exactly. It is about 250 feet deep; and about 2½ miles below this point are the falls of the river. Here the stream breaks through the lower sandstone, the second hard rock of the series, perhaps 250 feet below the top of the cañon. The falls are about 30 feet high, and just below them the gorge may be 100 feet across and 50 feet high, besides the cañon above it, which may be 300 feet higher, and at the top one-third of a mile wide. Down this gorge I rode, having soon found a way to get down into it. At about 5 miles below, I found it gradually widening and becoming more like the cañon in the other places. When I came within sight of our first camp on the cañon-wall, given in sheet No. 6, I rode up on to the prairie and back to camp. At this point the cañon-walls may have been 450 feet high and half a mile wide. I am confident this is the place so vividly described in Marcy and McClellan's Red River Report, (p. 55,) as I have traced up or down every cañon which could fit their description, and this comes the nearest to doing it.

The narrowest and deepest cañon met by us, in a month's steady search of them, is that pictured by me as Tule Cañon, which is 500 feet deep by the barometer, and about a qaurter of a mile wide from top to top. The steepest and highest cliff seen is that painted in the center of the picture, and it is 125 feet by the barometer. During our stay in this region the closest search of the members of the party failed to detect or to find any signs of fossils in the main cañon or above it in the two creeks forming the main stream. I except from this statement the petrified trunks of trees which were occasionally seen, and petrified rootlets which were found in the upper clay just under the white or reddish-white limestone, which has been so often referred to as the capping stone of the region.

We remained five days in camp at the head of Cañoncito Blanco. This enabled me to take astronomical observations for longitude and

latitude, and to run a stadia-line down the canon, and to make investigations into geology. Here we were rewarded for the first time by the discovery of water-worn lamellibranchiata *Ostræa*, *Gryphæa*, and others, so worn as to be unrecognizable. The place where found, and a more particular description, will be given further on. This cañon is sharply cut, narrow, and soon very deep, reaching in about 2½ miles the same depth acquired by the main stream in 10½. There is found in the course of the stream, which contained fresh sweet water in a running brook, a narrow falls, some 15 feet high. At the last point reached by the stadia-line, as shown on Sheet No. 9, the view of the distant cañon of the main stream was very fine, and the wild masses of weather-worn rocks seemed in their strangest confusion and brightest colors. The channel of the river was about 4 miles distant from the last point reached on the mesa. The narrow cañon, as is the same case below the falls of the Red River, had a choice covering of deciduous trees, where the protection from storms and fires was perfect and the water in abundance. Birds found the cañon a natural abiding place; and there were tracks of bears, and perhaps a "mountain-lion," though we saw neither. An unfortunate buffalo straggled to the stream during our stay, and, though despised by his comrades, he seemed to be welcomed by our escort "with bloody hands to a hospitable grave." A heavy hail-storm on June 6 gave unexpected and unnecessary animation to our stay.

As we left this point, on the 7th June, a caravan of New Mexicans, with women and children, flocks and herds, came into camp, having taken the night for their march, as is preferred by them. They were going as settlers to the Quita Que country to the south of us, and as we were traveling over the field traversed, in 1872–'73–'74, by the cavalry in chase of renegade Indians, the sudden appearance of this peaceful hegira was an evidence of the improved state of affairs.

We found good water at our next camp, which was at the head of a small cañon as it broke through the mesa. Indeed, from what the guides reported, and from what I deduce from the geological relations of the region, good water may be found near the head of any side cañon to the west, or north and west of the main cañon at points where the two water-bearing rocks, the upper or limestone near the surface, and the lower conglomerate some 350 feet below the upper level, crop out into the section. I say *may* be found, and an inspection will soon show whether or not a search would be worth while; because the highest point or line on the plains is directly west of the main cañon, and the water flowing eastward is in general following a direct course, or, at most, is gathered by gentle slopes into troughs, which empty into the side cañons. Any water flowing into the streams from any source below the conglomerate may be tainted from the gypseous formation and its concomitants. So the streams to the north, Mulberry Creek and Battle Creek, have only a limited source of supply, and that from the north; while the side cañons of the main cañon to the south and east of the great bend need not be searched for good water.

In traveling up the bed of the main river from the mouth of the Tule, each side cañon to the left may be explored in the confident belief of finding good water in a distance of a mile at least, while the streams from the north and east, containing a much larger flow of water, are inexpressibly nasty to the taste—worse than the main stream in fact, and upon examination the sources of these side affluents may be found within a mile or so of the main bed.

The descent from the edge of the mesa into the cañon of Tule Creek was made with difficulty by the wagons, and the fall of about 1,000 feet was effected in 3 miles.

The topography of this region is well illustrated by Sheet No. 11. We were now fairly in the alkali region, and the water of the Tule was serviceable without the addendum of soap. The valley was verdant with rank vegetation, and through part of its course had good groves of deciduous trees. The camp was established at the mouth of the stream, and I went to the head of the creek and found it of the same characteristics as described for the Palo Duro and Tierra Blanca. The creek is, however, of good length and volume of water, and where it broke into its cañon I saw the finest exhibition met with during the trip of the perpendicular-walled cañon. It was impossible to descend with the horses, and only after some two hours of hard climbing did we reach the bottom. The barometer showed a fall of 500 feet. While making this trip we saw another New Mexican emigrant with two wagons at the crossing of the stream above the head of the cañon. My return to camp found the party amply satisfied with four days of epsom salts, and we were ready to move the next day. The sketch showing the mouth of Tule Creek is made from its south bank, and looking north the river-bed may be half a mile wide, and as it glitters in the sun is as dazzling almost as snow. The quivering heat and the disagreeable odor make the passage up its bed even for 3 miles, at 5 o'clock in the morning, anything but pleasant.

Our camp on Battle Creek was on the scene of an encounter between Col. N. A. Miles, Fifth Infantry, and the hostile Indians, on August 30, 1874. Between Tule Creek and D Company Creek we made two marches among the rolling plains and hillocks at the foot and along the edge of the Staked Plains. Just before reaching D Company Creek we crossed Mulberry Creek. These streams have a limited supply of brackish water, and, although they may furnish a limited area for stock purposes, they will not, I fear, ever be of much value.

The scrubby cedars, which enjoy a growth in all situations where sand and drought make their existence pleasant, are here found, as well as scattering on the sides of the cañons anywhere and everywhere. We killed at D Company Creek a black bear, the only one seen on the trip, and a scrubby fellow at that.

During the camp at the mouth of the Tule the party feasted on deer, antelope, buffalo, young and old, to their heart's content, and until pork again grew to be a luxury.

We were now in the buffalo country, but, instead of the countless herds of five years before, the bands were small and not numerous. Thousands ran where tens of thousands were found in 1872, and the great numbers of maimed who had, though wounded, escaped the knife of the buffalo-hunter, testified to the approaching doom.

We encountered these herds from this time until our arrival at Camp Supply, and we met occasional parties of hunters hanging on the flanks of the herd. The buffalo are already so few in number that the pursuit is not very remunerative, and I doubt if any who were out made much more than a fair living by their campaign. Indeed, one of our scouts told me "it didn't pay," and as he himself was engaged in this work when most attractive, and had made with one partner $975 in two weeks, from skins obtained in the Arkansas Valley, in 1873, he probably knew. He gave me this as the best he had done.

From D. Company Creek we again ascended to the plains and connected our line with that of the outgoing part, at the camp at Mulberry Creek. Leaving the party in camp here, I rode southwest to the cañon again, and down and across it to a point not far from our Camp Cent. Lieutenant McCauley had made a reconnoissance from the camp on Tule Creek up to this point, and I now connected my line with his. A part

of the topography thus given is found on the sheets, but the whole cannot be put down until a general map is made; but I have not as yet been able to commence this. The cañon here has magnificent proportions. At the point where I descended the walls, it may be 8 miles wide, though it spreads as the lower course of the stream turns southwardly. The upper walls may be 300 feet high, and a plateau then stretches to near the river proper. The plateau is seamed with water-courses, and the main walls are indented by "breaks." The river-bed has immediate inclosing-hills of 300 or more feet in height, and on the west the mesa-walls rise nearer the river and are more sharp. The short water-courses of the plateau are the affluents from the north quoted by Marcy and McClellan. During this ride I found a few shells in a conglomerate, about 200 feet or more above the river, and at the place we camped. Perhaps the spot was 3 or 4 miles from Camp Cent. During my absence Lieutenant Woodruff ran a short line down Mulberry Creek, and the evening of my return to camp was celebrated by a brisk hail-storm and an attempt at stampede of the mules.

From this point we returned directly to Fort Elliott. The line of march was to the east of that taken on the outward march. The prismatic compass-line was the only one recorded on the return.

We camped on McClellan Creek, at the junction of its two forks, and in the fine grove of cottonwoods already spoken of. Reaching Fort Elliott June 21, the escort was returned to duty at its post, and it gave me pleasure to express to the commanding officer the entire satisfaction felt at the willingness, interest, and soldierly bearing of the escort, during their performance of the duty expected of them.

We arrived at Dodge City on June 28. The general mileage made was as follows:

	Miles.
Stadia line complete	260
Prismatic compass-line	450
Horseback reconnaissance	175
Total	885
Fort Dodge to Fort Elliott and return	370
Total mileage surveyed and by wagon	1,255

The general results were gratifying in showing that my map of the Indian Territory was quite correct, and my survey but confirmed my deductions and conclusions from prismatic compass-lines already on hand.

On working up the report I have met with much difficulty. Soon after coming back Lieutenant Woodruff was detailed in the office to work up his own notes, but was soon relieved and went with his regiment to Dakota. Lieutenant McCauley was afterward on duty but to be relieved and ordered to Washington. I myself was absent two months and a half, and I had no funds to hire a draughtsman. I have made some remarks in my geological notes which may be of interest as to the features of the country. As to its economical value it will be recollected that my notes commence and end at or near the Staked Plains, and that, whatever may be the future of the country, the needs for it are not apparent as yet; and with the miles and miles of fair grazing-land in the Indian Territory and in Kansas as yet unflecked with peaceful herds, I see no reason for speculating on the use of the Staked Plains. For the present it will suffice us to know where we may go and how we shall best travel, and where the best roads, wood, water, and grass may be found.

REPORT OF LIEUTENANT THOMAS M. WOODRUFF, FIFTH INFANTRY.

FORT LEAVENWORTH, KANSAS, *February* 1, 1877.

SIR: I have the honor to submit the following report upon my trip from the permanent camp on Red River to the Canadian River:

In accordance with your instructions to run the stadia line up to the Canadian River, I organized my party, consisting of Sergt. G. A. Lichtenberg, Company D, Engineers; scout Dixon, with one corporal and eight men; one wagon and seven-days' rations and forage, as follows: To Sergeant Lichtenberg I intrusted the keeping of the prismatic compass and odometer readings. The scout Dixon and Corporal Merriam, of Company M, Fourth Cavalry, rode some distance in advance and chose stations. Private Replogle had the stadia rod, and privates Hall, Kirch, and Hope assisted me as flagmen. I myself took Aloe theodolite No. 93. Scout Dixon informed me that it was quite a long distance from the permanent camp to the next water; therefore, in order to gain time and run the line more quickly, I left the camp at 1 o'clock on the 23d of May, taking only the working party, and ran the line out about 5 miles. I returned to the camp about 6 p. m. The afternoon had been cloudy, but very cool and pleasant.

At 5 o'clock on the morning of the 24th of May, I left the camp with my whole party and reached the last station of the previous day at 6.30 o'clock. The morning was cold and cloudy, with a heavy mist; cool, northerly wind. Everything, however, was favorable for taking readings, and I made rapid progress until 9.30 o'clock, when the sun came out very bright, driving away the mist. Soon after this, and during the remainder of the day, the mirage troubled me a great deal, and the heat was intense. About 11.30 o'clock a troop of about a dozen wild horses came very near my party—so near, in fact, as almost to stampede our horses. The wild horses were very fleet, and were not at all curious, for they kept on their course without stopping. They presented a beautiful sight as they galloped swiftly past.

Scout Dixon had conducted the wagon and the portion of the detachment not working with me to a point near the head of the Rio Piedroso, where we camped, reaching this place about 3.15 in the afternoon. The distance from the permanent camp was 17 miles 1,137 yards. The country over which we had passed during the first part of the day, for about 14 miles presented all the characteristics of the Staked Plain; the remainder was gently rolling, indicating the proximity of a stream. At our camp we found a series of pools of good, clear water, apparently permanent springs. There were a few cottonwood trees, and the grazing for the animals was good. While my dinner was being prepared I made collections of botanical and entomological specimens, which were about the same as those that I had collected at the permanent camp.

On the 25th I broke camp at daylight and left at 5.20, taking nearly a northwesterly direction; the country became more and more hilly, and finally very much cut up with deep arroyas. We reached camp about midday, having made 10 miles 881 yards. The day was cool and pleasant, and fine for working. Our camp was located about a mile above the mouth of May Creek, which runs into the Canadian. As we neared the Canadian I noticed that the hills were composed largely of drift, with outcroppings of limestone and red and yellow sandstone. Our camp on May Creek was in a very pretty little grove of cottonwood. The water here was not very good, being slightly alkaline. After dinner I walked down the creek to the river, which I found contained a large flow of water, and the bed was about 300 yards wide. On the north side of the Canadian the bluffs were more abrupt and higher than on the south. On the west bank of May Creek, right at its mouth, there is a hill about 60 feet in height, on the top of which I found a space of about 12 feet square, marked out by stones; it seemed to be a grave, and after digging and scraping around with my sheath-knife I found several arrow-heads of flint. I should like to have investigated this further, but I had to return to camp before darkness set in.

On this same day Sergeant Lichtenberg and scout Dixon went some 5 miles up the river, the sergeant making a very accurate topographical sketch accompanying his notes.

On the 26th I broke camp at daylight. I sent Sergeant Lichtenberg with a small guard and the wagon back to our camp of the 24th. I ran the stadia line about 5½ miles down the river; it consumed a great deal of time, owing to the very rough nature of the ground. My last station was on a very high hill, near the mouth of Muster Creek or the Arroya Bonita, in the valley of which, some 3 or 4 miles distant, were several large cottonwood groves. On the hills that I this day passed over, I remarked the frequency of cedar trees, of a rather stunted growth; there were some, however, that attained considerable height. I suppose that the general level of the tops of these hills, which were largely composed of gravel, was about 150 feet above the valley of the Canadian. A little below the mouth of the Arroya Bonita the Canadian makes a sharp turn toward the north, forming, I suppose, the Great Bend. From our camp of the previous night to this point our course had been nearly east. After making a topographical sketch I assembled my party, and taking about a southerly

course over country similar to that that we had just passed over, we arrived at our camp of the 24th instant about 2 o'clock, having had a very hard day's work.

On the 27th I broke camp at 5 o'clock, and reached the permanent camp on Red River at 10.30 a. m. It is a curious fact that during the three nights, while I was on this reconnaissance, we had very heavy rains, accompanied by thunder and lightning, and this in a region that has always been thought to be very dry.

I am, sir, very respectfully, your obedient servant,

THOS. M. WOODRUFF,
Lieutenant Fifth Infantry.

Lieut. E. H. RUFFNER,
Corps of Engineers,
Chief Engineer Department of the Missouri.

METEOROLOGICAL REPORT.

As the country to be traversed was but a rolling prairie, and the differences in altitude were not expected to be very great, it was thought a constant reference could be made to a barometrical base at Dodge City; one of the stations of the signal-service of the Army; a point at no time more than 225 miles distant from the working parties. Any inaccuracies arising from the necessary assumption that abnormal changes of pressure at the one station were probably equally experienced at the other, were believed to be less than would be errors in the determination of a mean barometrical reading for a station occupied for the short time which could at best be devoted for this purpose. Two or three points were to be determined by several days' barometrical observations, and the difference of altitude between these points and Dodge City being determined by this series, the relative altitudes of neighboring points would probably be fairly accurate.

In conducting the survey three points in the field were occupied long enough to enable parties to make surveys in various directions, thus determining at the same time with the other work profiles of the lines surveyed. The instruments used were a mountain barometer, No. 392, made by J. Green, of New York, and two aneroids made by Cassella, and marked B and C. The tube of the mountain barometer was broken twice on the trip, but the frequent comparisons between the aneroids and the mercurial during the survey, and the comparison between all of these instruments and the barometer at the Dodge City station, both going and coming, gave satisfactory results, and proved the instruments to be good ones. I did not have a wet-bulb thermometer, and the observations for humidity are therefore wanting. As the general character of the country is very nearly the same as at the meteorological base, it is probable that but little difference in the condition of the atmosphere arose from this reason, and it is certain that the error arising from the omission of the humidity-terms is less than that which necessarily was introduced by the starting assumption of comparing our observations with the distant base.

HORARY CURVES.

Horary curves were determined wherever practicable, and great care was taken that these observations should be as accurate as possible. The following table of corrections is given, determined on the dates noted.

Altitude.	Dodge City, Kans., April 26 and 27, and June 28 and 29.	Fort Elliott, Tex., May 6 and 10, inclusive, and June 21 and 22.	Tule Creek Camp, June 9 and 11, inclusive.	Camp Supply, April 30 and May 1 and 3, inclusive.	Mulberry Creek, June 17 and 18.	Cañoncito Blanco, June 5 and 6.
	2,479 feet.	2,595 feet.	2,290 feet.	1,901 feet.	3,106 feet.	3,491 feet.
7 a. m	—.011	—.039	—.076	—.004	—.035	—.031
8 a. m	—.040	—.048	—.067	—.037	+.003	—.017
9 a. m	—.043	—.039	—.050	—.055	+.011	—.023
10 a. m	—.044	—.034	—.032	—.063	—.005	—.033
11 a. m	—.044	—.014	—.022	—.050	+.002	—.041
12 m	—.025	—.005	—.012	—.026	+.001	—.023
1 p. m	+.003	+.016	—.004	—.002	+.003	—.011
2 p. m	+.006	+.030	+.007	—.008	+.011	—.007
3 p. m	+.027	+.031	+.032	+.014	+.015	+.057
4 p. m	+.040	+.046	+.060	+.058	+.015	+.050
5 p. m	+.044	+.027	+.083	+.071	+.019	+.060
6 p. m	+.053	+.026	+.083	+.074	+.018	+.053
7 p. m	+.053	+.014	+.059	+.088	+.015	+.040
8 p. m	+.033	—.004	+.034	+.081	+.011	+.025
9 p. m	+.004	—.033	+.028	+.028	+.007	+.036
10 p. m	—.004	—.016	+.020	......	......	......
11 p. m	—.015	—.023	+.015	......	......	.00
12 a. m	—.008	—.011	+.013	......	......	......
1 a. m	—.012	+.012	—.010	......	......	+.012
2 a. m	—.009	+.034	—.021	......	......	......
3 a. m	—.014	+.047	—.032	......	......	......
4 a. m	—.002	+.020	—.033	......	......	......
5 a. m	—.023	—.017	—.047	+.002	......	......
6 a. m	—.008	—.029	—.068	+.003	—.055	—.023

A partial determination of horary corrections was made at the following points:

Altitude.	Permanent camp Red River, May 21, 28, 31, inclusive.	First camp on Red River, May 18 and 19.
	3567.7 feet.	3434.
7 a. m	—.049	—.083
10.27 a. m	—.059	—.074
2 p. m	+.047	......
3 p. m	+.072	+.049
9 p. m	+.090	+.034
10 p. m	+.007	......
6 a. m	—.038	—.086

These tables are prepared from, at best, but a limited number of observations, and should not be considered as more than approximate. At the individual points, however, the determinations seem to have been fairly accurate, judging from the closeness of the range. At Dodge City the horary curve was determined for April 26 and 27 and for June 28 and 29. The mean of the range between individual hourly results, as de-

termined by the two series, is 0''.013 of the barometical scale. Although probably an accident, this close agreement between results at times two months apart shows that the values of the corrections are probably safely close in calculating the differences of altitude during the intervening period. Five days' record at Fort Elliott and four at the camp on Tule Creek gave each as the mean of the range in the results for determination of individual hour corrections 0''.019 of the scale. This close agreement is also a satisfactory evidence of probably equally accurate and close results. These three points have about the same altitude, and are but a degree distant in longitude. We might expect, I presume, a closer agreement between the three curves than is exhibited, but I think myself that the location of the camp on Tule Creek, being in a cañon 1,200 feet deep, with walls at least 4 miles distant in any direction, and thus probably affected by rapid heating of the somewhat confined body of air, probably presents causes for rapid and great variation of the pressure not experienced by the prairie-situations of the other two points. The curve at Fort Elliott was determined from the mean of five days' observations, excepting the corrections for the hours between 10 p. m. and 5 a. m., which depend upon one day's observations only. If we omit these hours, we shall see a close agreement between the curves of this place and of Dodge City. It may not be uninteresting to compare the table of corrections obtained by taking the mean of these two determinations with the table used by Lieutenant Whipple, in his survey of the 35th parallel, (Pacific Railroad Reports, vol. iv, p. 257,) and applied to the barometical observations between camp 32 and the Laguna Colorado, essentially the same country.

The scale used by Lieutenant Whipple was deduced from observations at Washington and Philadelphia, and modified to conform to the supposed climate.

The mean deduced by myself may be considered as that of seven days' observations in May for a point at an altitude of 2,500 feet, latitude 35° 30' and longitude 100° west from Greenwich. The differences given between the two series are obtained by subtracting Lieutenant Whipple's curve from mine.

TABLE COMPARING HORARY CORRECTIONS.

	Lieut. Whipple 1853.	Lieut. Ruffner, 1876.	Difference.
6 a. m	−.007	−.018	−.011
7 a. m	−.020	−.025	−.005
8 a. m	−.030	−.044	−.014
9 a. m	−.040	−.041	−.001
10 a. m	−.050	−.039	+.011
11 a. m	−.055	−.029	+.026
12 m	−.025	−.015	+.010
1 p. m	−.005	+.009	+.014
2 p. m	+.015	+.018	+.003
3 p. m	+.030	+.029	−.001
4 p. m	+.045	+.043	−.002
5 p. m	+.050	+.036	−.014
6 p. m	+.030	+.039	+.009
7 p. m	+.020	+.034	+.014
8 p. m	+.005	+.014	+.009
9 p. m	+.000	−.014	−.014

The agreement between the two series from and after the 12 m. correction is noticeable. The maximum of Lieutenant Whipple's curve was placed at 11 a. m., an assumption which later authorities have corrected. I believe at most of the interior stations of the United States the maxi-

mum is now given between 9 and 10 a. m., or nearly there. Of the remaining series, the one at Mulberry Creek is not considered reliable, as the determination rests upon 24 hours' readings only, and the only really violent storm of the trip occurred there. The camp was situated also in a narrow cañon, and I am now inclined to believe such locations entirely unsuitable for barometrical observations.

Thinking that the elements used in calculating the various horary curves might be of service in the future, I have prepared the following table, giving the horary corrections as determined by each day's observations, and following the mean of the results for each is the mean of the variations of individual results from their mean.

HORARY CORRECTIONS AS GIVEN BY THE OBSERVATIONS DURING EACH 24 HOURS.

	Dodge City, Kans.			Fort Elliott, Tex.							Tule Creek, Tex.				
	April 26 and 27.	June 28 and 29.	Mean.	May— 6.	7.	8.	10.	June 22.	Mean.	$\frac{\Sigma v}{m}$	June— 9.	10.	11.	Mean.	$\frac{\Sigma v}{m}$
7 a. m.	−.025	−.002	−.011	−.042	−.019	−.029	−.047	−.053	−.039	.011	−.096	−.056	....	−.076	.020
8 a. m.	−.059	−.022	−.040	−.082	−.029	−.019	....	−.060	−.048	.024	−.072	−.063	....	−.067	.005
9 a. m.	−.048	−.038	−.043	−.062	−.029	−.009	....	−.059	−.039	.018	−.073	−.044	−.034	−.050	.015
10 a. m.	−.043	−.044	−.044	−.052	−.019	+.001	−.057	−.045	−.034	.020	−.061	−.020	−.015	−.032	.019
11 a. m.	−.039	−.049	−.044	−.012	−.009	+.031	−.047	−.033	−.014	.021	−.049	−.004	−.009	−.022	.017
12 m.	−.035	−.015	−.025	+.008	+.011	+.011	−.037	−.020	−.005	.016	−.040	+.010	−.004	−.012	.019
1 p. m.	+.016	−.011	+.003	+.028	+.021	....	+.013	+.003	+.016	.009	−.007	+.021	−.026	−.004	.033
2 p. m.	+.009	+.003	+.006	+.058	+.021	....	+.013	+.022	+.029	.015	+.023	+.041	−.042	+.007	.033
3 p. m.	+.027	+.027	+.027	+.078	+.021	+.001	+.023	+.029	+.031	.019	+.052	+.056	−.011	+.032	.029
4 p. m.	+.049	+.031	+.040	+.088	+.021	....	+.033	+.042	+.046	.021	+.084	+.086	+.010	+.060	.032
5 p. m.	+.042	+.046	+.044	+.058	+.011	+.001	+.023	+.044	+.027	.019	+.074	+.124	+.051	+.083	.028
6 p. m.	+.047	+.060	+.053	+.028	+.001	....	+.043	+.037	+.027	.013	+.089	+.118	+.039	+.083	.028
7 p. m.	+.043	+.064	+.053	−.028	−.049	+.021	+.053	+.019	+.015	.025	+.054	+.090	+.033	+.059	.021
8 p. m.	+.038	+.028	+.033	−.002	−.049	−.039	+.053	+.019	−.004	.032	+.056	+.001	+.049	+.034	.023
9 p. m.	+.006	+.002	+.004	−.042	−.079	−.039	−.007	+.002	−.033	.024	+.045	+.004	+.035	+.028	.016
10 p. m.	−.004	−.004	−.004	....	....	....	....	−.016	−.016	....	+.028	+.007	+.025	+.020	.009
11 p. m.	−.009	−.020	−.015	....	....	....	....	−.023	−.023	....	+.021	+.009	+.032	+.021	.016
12 a. m.	+.010	+.006	+.008	....	....	....	....	−.011	−.011	....	+.023	+.003	+.014	+.013	.007
1 a. m.	−.012	....	−.012	....	....	....	....	+.012	+.012	....	+.005	−.069	+.033	−.010	.039
2 a. m.	−.009	....	−.009	....	....	....	....	+.034	+.034	....	−.007	−.071	+.016	−.021	.033
3 a. m.	−.015	−.013	−.014	....	....	....	....	+.047	+.047	....	−.024	−.065	−.008	−.032	.022
4 a. m.	+.005	−.009	−.002	....	....	....	....	+.020	+.020	....	−.030	−.030	−.040	−.033	.004
5 a. m.	−.022	−.024	−.023	−.012	−.019	−.019	−.027	−.008	−.017	.006	−.033	−.051	−.057	−.047	.009
6 a. m.	+.013	−.030	−.008	−.062	+.011	−.029	−.037	−.027	−.020	.017	−.060	−.064	−.079	−.068	.008
Mean of range between results	....	....	±.013	....	....	....	....	....	....	±.018	....	....	....	....	±.019

Camp Supply, Indian Territory.

Hour.	May. 1.	May. 2.	May. 3.	Mean.	$\frac{\Sigma v}{m}$	Hour.	May. 1.	May. 2.	May. 3.	Mean.	$\frac{\Sigma v}{m}$
5 a. m....	−.019	....	+.021	+.002	.020	2 p. m....	+.002	−.004	−.022	−.008	.009
6 a. m....	−.026	+.035	+.003	+.003	.020	3 p. m ...	+.034	+.003	+.006	+.014	.003
7 a. m....	−.062	+.032	+.017	−.004	.039	4 p. m....	+.058	....	....	....	.....
8 a. m....	−.079	−.004	....	−.037	.042	5 p. m....	+.071	....	....	+.071	.....
9 a. m....	−.106	−.004	....	−.055	.051	6 p. m....	+.074	....	....	+.074	.....
10 a. m....	−.112	−.017	−.062	−.063	.032	7 p. m....	+.088	....	....	+.088	.....
11 a m....	−.059	−.040	....	−.050	.009	8 p. m....	+.081	....	....	+.081	.....
12 m	−.026	....	....	−.096	......	9 p. m....	+.084	−.001	+.004	+.028	.035
1 p. m....	−.002	....	....	−.002	......						
Mean of range between results........											±.027

Permanent Camp on Red River, Texas.

Hour.	May. 21.	May. 28.	May. 29.	May. 30.	May. 31.	Mean.	$\frac{\Sigma v}{m}$	Mean, May 21, 28, 29.	$\frac{\Sigma v}{m}$
6 a. m	−.044	+.02	−.010	−.067	−.087	−.038	.031	−.012	.016
7 a. m	−.046	+.02	−.028	−.077	−.105	−.049	.032	−.017	.016
10.27 a. m..................	−.041	−.03	−.027	−.185	−.013	−.059	.050	−.033	.006
2 p. m	+.002	.00	+.054	+.047	+.130	+.047	.036	+.017	.020
8 p. m	+.079	.00	+.046	+.076	+.157	+.072	.049	+.042	.028
9 p. m..................	+.041	−.02	−.044	+.021	+.100	+.020	.029	−.008	.034
9.27 p. m..................	+.045	−.02	−.048	+.006	+.050	+.007	.035	−.008	.035
Mean of range between results........							±.037	....	±.022

I can offer no explanation which can account for the extreme range in the results at this point, but that the final results are of value may be seen in the fact that the probable error of the final results and of a single observation for the altitude of this point deduced from comparisons with the record at Dodge City is almost the same as the same quantities deduced in the same way for the mouth of Tule Creek, a point where the range in the determination of the horary corrections was only half as great as at this camp. On the 30th and 31st of May great disturbance in the atmospheric pressure is reported at Dodge City. If these two days are omitted, the corrections become very nearly the same as those obtained for the general table, there being only an average difference of +0.005 inch between the two series in individual readings. I did not feel justified in throwing out these two days entirely, and they are incorporated in the work and included in the determination of the altitude.

Abnormal and monthly variations are not given, as the occupation of any one point was not lengthy enough to make any proper deduction therefrom. The barometrical pressure curve at Dodge City is given for the time of the operations of the survey, and also the curve of pressure of the barometers of the survey, reduced to the altitude of Dodge City.

In comparing these two curves, differences may arise from the following causes:

1st. Errors of reading the instruments at the two stations.

2d. Imperfections in the instruments themselves.

3d. Atmospheric changes affecting one station and not the other.

4th. Errors in supposed differences of altitudes used in reduction.

5th. Errors in reduction.

Assuming the personal and instrumental errors constant, and that

observations, if sufficiently continuous at two stations, will wholly or partially eliminate the errors from the third source, comparisons between the curves will give us a means of comparing the probable errors arising from the fourth cause, and will give us a correction of more or less value, depending upon the length of time of the observations and the distance between the stations. I have found by this means the following corrections for the deduced altitudes of the principal points:

Place.	Correction to altitude.	Probable error of altitude as deduced from observation.	
		Single observation.	Final result.
	Feet.		
Camp Supply	+41.4	±51.2	±15.5
Fort Elliott	— 6.7	±22.2	± 5.2
Red River Permanent Camp	+10.0	±37.2	± 8.1
Tule Creek	+20.1	±37.2	±10.
Cañonsito Blanco	—60.7	±58.0	±16.7

TABLE OF BAROMETRICAL READINGS AT DODGE CITY, UNCORRECTED FOR ALTITUDE, AND OF THE BAROMETRICAL READINGS TAKEN ON THE LINE OF THE SURVEY, REDUCED TO THE ALTITUDE OF DODGE CITY.

Date.	Dodge City. Reduced to 32°.	Line of survey. Reduced to 32°.	Difference.	Station occupied on survey.
April 27, 2 p. m.	27.291	27.282	—.009	On the road.
9 p. m.	.405	.462	+.057	Bluff Creek.
April 28, 7 a. m.	.493	.451	—.042	On the road.
2 p. m.	.411	.408	—.003	Redoubt Creek.
9 p. m.	.377	.343	—.044	Do.
April 29, 7 a. m.	.360	.267	—.093	On the road.
2 p. m.	.240	.238	—.002	Do.
9 p. m.	.227	.133	—.094	Sand Creek.
April 30, 7 a. m.	.144	.073	—.071	Do.
2 p. m	.107	.027	—.080	Camp Supply.
9 p. m.	.114	.047	—.067	Do.
May 1, 7 a. m.	.374	.207	—.167	Do.
2 p. m.	.493	.462	—.031	Do.
9 p. m.	.636	.587	—.049	Do.
May 2, 7 a. m.	.721	.717	—.004	Do.
2 p. m.	.598	.637	+.039	Do.
9 p. m.	.439	.497	+.058	Do.
May 3, 7 a. m.	.205	.292	+.087	Do.
2 p. m.	26.985	.011	+.026	Wolf Creek.
9 p. m.	.917	26.875	—.042	Do.
May 4, 7 a. m.	27.067	.875	—.192	Do.
2 p. m.	.169	27.169	000	On the road.
9 p. m.	.212	.207	—.005	South Commission Creek.
May 5, 7 a. m.	.227	.196	—.031	On the road.
2 p. m.	.147	.155	+.008	Do.
9 p. m.	.158	.167	+.009	Washita River.
May 6, 7 a. m.	.033	26.986	—.047	On the road.
2 p. m.	.084	27.076	—.008	Fort Elliott, Texas.
9 p. m.	.272	.276	+.004	Do.
May 7, 7 a. m	.449	.436	—.013	Do.
2 p. m.	.425	.456	+.031	Do.
9 p. m.	.515	.571	+.056	Do.
May 8, 7 a. m.	.478	.526	+.048	Do.
2 p. m.	.501	.491	—.010	Do.
9 p. m.	.538	.546	+.008	Do.
May 9, 7 a. m.	.507	.546	+.039	Do.
2 p. m.	.395	.446	+.051	Do.
9 p. m.	.390	.446	+.056	Do.
May 10, 7 a. m.	.385	.436	+.051	Do.
2 p. m.	.355	.346	—.009	Do.
9 p. m.	.299	.346	+.047	Do.
May 11, 7 a. m.	.301	.376	+.075	Do.
2 p. m.	.373	....	....	
9 p. m	.473	.382	—.091	Old Cantonment.

Table of barometrical readings at Dodge City, &c.—Continued.

Date.	Dodge City. Reduced to 32°.	Line of survey. Reduced to 32°.	Difference.	Station occupied on survey.
May 12, 7 a. m	27.612	27.607	−.005	Old cantonment.
2 p. m	.523	.557	+.034	Do.
9 p. m	.473	.487	+.069	Do.
May 13, 7 a. m	.420	....	....	
2 p. m	.346	....	....	
9 p. m	.311	.330	+.019	Big Springs.
May 14, 7 a. m	.206	.189	−.017	On the road.
2 p. m	.130	.174	+.044	McClellan Creek.
9 p. m	.095	.139	+.044	Do.
May 15, 7 a. m	.073	.129	+.056	Do.
2 p. m	.071	.229	+.158	Do.
9 p. m	.224	.169	−.055	Do.
May 16, 7 a. m	.429	.430	+.001	On the road.
2 p. m	.392	.334	−.058	Salt Fork.
9 p. m	.336	.399	−.063	Do.
May 17, 7 a. m	.351	.352	+.001	On the road.
2 p. m	.278	.401	+.123	Mulberry Creek.
9 p. m	.230	.316	+.086	Do.
May 18, 7 a. m	.250	.260	+.010	On the road.
2 p. m	.185	.178	−.007	Red River, first camp.
9 p. m	.162	.278	+.116	Do.
May 19, 7 a. m	.303	.333	+.030	Do.
2 p. m	.279	.313	+.034	Do.
9 p. m	.261	.353	+.092	Do.
May 20, 7 a. m	.274	.300	+.026	On the road.
2 p. m	.248	.237	−.011	Red River, permanent camp.
9 p. m	.238	.222	−.016	Do.
May 21, 7 a. m	.233	.277	+.044	Do.
2 p. m	.199	.207	+.008	Do.
9 p. m	.194	.147	−.047	Do.
May 22, 7 a. m	.213	.202	−.011	Do.
2 p. m	.157	.187	+.030	Do.
9 p. m	.395	....	....	
May 23, 7 a. m	.504	.437	−.067	Red River, permanent camp.
2 p. m	.505	.372	−.133	Do.
9 p. m	.558	....	....	
May 24, 7 a. m	.599	.527	−.072	Red River, permanent camp.
2 p. m	.569	.510	−.059	Palo Duro First.
9 p. m	.599	.590	....	
May 25, 7 a. m	.557	.610	+.053	Palo Duro First.
2 p. m	.500	.611	+.111	Palo Duro Second.
9 p. m	.466	.631	+.165	Do.
May 26, 7 a. m	.503	.651	+.148	Do.
2 p. m	.453	.671	+.218	Do.
9 p. m	.430	.611	+.181	Do.
May 27, 7 a. m	.441	....	....	
2 p. m	.387	.297	−.090	Red River, permanent camp.
9 p. m	.367	.287	−.080	Do.
May 28, 7 a. m	.320	.287	−.033	Do.
2 p. m	.249	.307	+.058	Do.
9 p. m	.292	.327	+.035	Do.
May 29, 7 a. m	.263	.307	+.044	Do.
2 p. m	.212	.167	−.045	Do.
9 p. m	.203	.207	+.004	Do.
May 30, 7 a. m	.123	.097	−.026	Do.
2 p. m	26.949	26.892	−.057	Do.
9 p. m	.886	.832	−.054	Do.
May 31, 7 a. m	.814	.847	+.033	Do.
2 p. m	.751	.702	−.049	Do.
9 p. m	.866	.847	−.019	Do.
June 1, 7 a. m	27.189	27.112	−.077	Do.
2 p. m	.151	.062	−.089	Do.
9 p. m	.181	....	....	
June 2, 7 a. m	.244	.032	−.212	Red River, permanent camp.
2 p. m	.306	.131	−.175	Cañoncito Blanco.
9 p. m	.455	....	....	
June 3, 7 a. m	.563	.461	−.102	Cañoncito Blanco.
2 p. m	.551	.531	−.021	Do.
9 p. m	.547	.551	+.004	Do.
June 4, 7 a. m	.569	.591	+.022	Do.
2 p. m	.488	.551	+.063	Do.
9 p. m	.486	.531	+.045	Do.
June 5, 7 a. m	.494	.644	+.150	Do.
2 p. m	.408	.590	+.182	Do.
9 p. m	.393	.517	+.124	Do.
June 6, 7 a. m	.319	.531	+.212	Do.
2 p. m	.208	.370	+.062	Do.
9 p. m	.136	.372	+.236	Do.
June 7, 7 a. m	.039	.224	+.185	On the road.

Table of barometrical readings at Dodge City, &c.—Continued.

Date.	Dodge City. Reduced to 32°.	Line of survey. Reduced to 32°.	Difference.	Station occupied on survey.
June 7, 2 p. m.	.091	.174	+.083	Camp Cent.
9 p. m.	.202	.319	+.117	Do.
June 8, 7 a. m.	.339	.324	—.115	On the road.
2 p. m.	.354	.330	—.024	Tule Creek.
9 p. m.	.312	.351	—.039	Do.
June 9, 7 a. m.	27.272	27.306	+.034	Do.
2 p. m.	.115	.141	+.026	Do.
9 p. m.	.067	.072	+.005	Do.
June 10, 7 a. m.	.111	.145	+.034	Do.
2 p. m.	.195	.111	—.084	Do.
9 p. m.	.323	.254	—.069	Do.
June 11, 7 a. m.	.420	.326	—.094	Do.
2 p. m.	.374	.366	—.008	Do.
9 p. m.	.405	.353	—.051	Do.
June 12, 7 a. m.	.656	.596	—.060	Do.
2 p. m.	.610	.562	—.048	Do.
9 p. m.	.565	.568	+.003	Do.
June 13, 7 a. m.	.532	....	....	
2 p. m.	.465	.475	+.010	Battle Creek.
9 p. m.	.450	.466	+.016	Do.
June 14, 7 a. m.	.442	.437	—.005	On the road.
2 p. m.	.373	.432	—.059	D Company Creek.
9 p. m.	.366	.452	+.086	Do.
June 15, 7 a. m.	.410	.479	+.069	Do.
2 p. m.	.348	.423	+.075	Do.
9 p. m.	.457	.460	+.003	Do.
June 16, 7 a. m.	.512	....	....	
2 p. m.	.416	.458	+.042	Mulberry Creek.
9 p. m.	.432	.472	+.039	Do.
June 17, 7 a. m.	.465	.547	+.082	Do.
2 p. m.	.466	.495	+.029	Do.
9 p. m.	.474	.534	+.060	Do.
June 18, 7 a. m.	.471	.586	+.115	Do.
2 p. m.	.409	....	....	
9 p. m.	.409	.566	+.057	Do.
June 19, 7 a. m.	.428	.327	—.101	On the road.
2 p. m.	.371	.428	—.057	Whitefish Creek.
9 p. m.	.356	....	....	
June 20, 7 a. m.	.335	.387	+.052	On the road.
2 p. m.	.270	.310	+.040	McClellan Creek.
9 p. m.	.259	.291	+.032	Do.
June 21, 7 a. m.	.226	.328	+.102	On the road.
2 p. m.	.188	....	....	
9 p. m.	.223	.114	—.109	Fort Elliott.
June 22, 7 a. m.	.294	.149	—.145	Do.
2 p. m.	.257	.067	—.190	Do.
9 p. m.	.351	....	....	
June 23, 7 a. m.	.397	.271	—.126	Do.
2 p. m.	.355	.186	—.169	Canadian River.
9 p. m.	.352	....	....	
June 24, 7 a. m.	.346	....	....	On the road.
2 p. m.	.278	.089	—.199	Willow Spring.
9 p. m.	.222	....	....	
June 25, 7 a. m.	.216	.120	—.096	Wolf Creek.
2 p. m.	.182	.052	—.130	Camp Supply.
9 p. m.	.189	.087	—.102	Do.
June 26, 7 a. m.	.219	.134	—.085	Do.
2 p. m.	.193	.126	—.067	On the road.
9 p. m.	.244	.113	—.131	Cimarron River.
June 27, 7 a. m.	.335	.271	—.064	On the road.
2 p. m.	.330	.312	—.018	Bluff Creek.
9 p. m.	.396	.372	—.024	Do.
June 28, 7 a. m.	.484	....	....	Dodge City.
2 p. m.	.506	....	....	Do.
9 p. m.	.521	....	....	

Mean barometric reading at Dodge City, 196 readings = 27″. 325.

v = Diff. reading, Dodge City and line of survey.

m = Number of observations = 167.

$$r = 0.8453 \frac{\Sigma v}{\sqrt{m(m-1)}} = 0.8453 \frac{11.680}{\sqrt{167 \times 166}} = \pm .0''.059.$$

This may be considered as showing the general conditions of accuracy of the barometrical determinations during the survey inasmuch as all the errors enumerated above have been here considered, and the resulting probable error reduced to feet $= \pm$ 56.5 feet may be useful in the comparison with other and similar series.

In preparing the following general table of altitudes the principal points occupied are referred to, and in the determinations the probable errors are calculated from the range in the various results. The accuracy of such comparison is doubtful and the formula should be applied to weighted observations, wherein the distance between the stations should enter. Some function indicating the amount of abnormal atmospheric disturbance should also enter, as is plainly indicated in the results of the determination at Camp Supply. As it is, however, the probable errors serve somewhat for comparison of the accuracy of results. The altitude of Dodge City was taken from the report of the Chief Signal Officer of the Army for 1876. The mean of the barometric observations at that point for the period in question gives a slightly different result. The column of No. of observations used, sometimes includes the mean of two barometers and at others of three. The profile of Tule Creek and of the Palo Duro and Tierra Blanca were obtained by using one barometer on the road, and comparing its record with that of one left at one of the camps occupied for a longer period.

TABLE GIVING ALTITUDES AND BAROMETRICAL READINGS AT POINTS OCCUPIED IN THE SURVEY OF THE SOURCES OF RED RIVER, TEXAS.

Dates when observations were made.	Station.	Difference in altitude between Dodge City and station occupied.	Number of observations used in determination.	Altitude.	Probable error of— Single result.	Probable error of— Final result.	Mean barometrical reading— Observed.	Mean barometrical reading— Deduced from difference in altitude and Dodge City mean.
		Feet.		*Feet.*				
	Dodge City			2,479			27.325	27.325
April 27 and June 27	Bluff Creek	− 75.1	3	2,404			27.439	27.399
April 27	Bear Creek Redoubt	− 471.4	1	2,008			.616	.820
April 28 and June 26	Redoubt Creek, Cimarron River	− 676.0	3	1,803			28.088	28.038
April 29	Kansas boundary	− 517.0	1	1,962			27.906	27.869
April 29	Gypsum Creek	− 960.4	1	1,519			28.096	28.346
April 29	Dog Soldier Creek	− 825.8	1	1,653			28.006	28.200
April 29 and 30	Sand Creek	− 825.8	2	1,653			27.971	28.200
April 30	Summit divide between Sand Creek and Beaver Creek	− 386.5	1	2,092			27.496	27.808
April 30 to May 3 and June 25	Camp Supply	− 577.7	11	1,901	±51.2	±15.5	28.106	27.934
May 3 and 4	Crossing Wolf Creek	− 533.3	3	1,946			27.463	.886
May 4	Willow Spring	− 387.7	2	2,091			.496	.732
May 4	South Commission Creek	− 237.7	1	2,241			.456	.574
May 5 and June 23	Canadian River	− 66.7	2	2,402			.241	.494
May 5	Washita River	+ 30.3	1	2,509			.136	.294
May 5 to 11 and June 21 and 22	Fort Elliott, Tex	+ 115.6	18	2,595	±22.2	± 5.2	.219	.205
May 12	Old Cantonment Creek	+ 218.2	3	2,697			.282	.099
May 13	Big Springs, North Fork	+ 269.0	1	2,748			.051	.046
May 14	Level of Staked Plains, between North Fork and McClellan Creek.	+ 550.7	1	3,030			26.599	26.757
May 14 and 15	McClellan Creek	+ 380.2	4	2,859	44.8	22.4	.775	26.932
May 16	Level plain between McClellan Creek and Salt Fork	+ 692.6	1	3,172			26.859	26.613
May 16	Salt Fork	+ 467.8	2	2,947			.883	.842
May 16 and June 16 and 17	Mulberry Creek	+ 626.8	7	3,106	29.5	13.2	.714	.680
May 18 and 19	First camp on Red River	+ 955.0	5	3,434	42.8	19.2	26.314	26.348
May 20, 22, 23, 28, to June 1	Permanent camp	+1,088.7	21	3,568	37.2	8.1	.153	.214
June 3 to 6	Cañoncito Blanco	+1,012.4	12	3,491	58.0	16.7	.455	.290
June 7	Camp Cent	+ 946.5	2	3,426			.278	.357
June 8 to 13	Mouth Tule Creek	− 189.1	14	2,290	37.2	10.0	27.518	27.523
June 13	Battle Creek	+ 131.0	2	2,610			.334	.169

June 14 and 15	D Company Creek	+ 298.2	4	2,777	26.8	13.4	.140	.016
June 19	Whitefish Creek	+ 548.6	1	3,028	....	....	26.862	26.759
June 20	McClellan Creek at the forks	+ 304.3	2	2,783	....	....	26.985	27.010
	Determined by comparison with permanent camp on Red River:							
May 24 and 29	First camp on Palo Duro	+1,131.7	3	3,611	32.8	18.9	26.416	26.171
May 25 and 26	Second camp on Palo Duro	+1,273.2	2	3,752	....	....	.340	.039
May 24	Rio Piedroso	+1,039.2	2	3,518	....	....	.543	.263
May 25	Canadian River	+ 755.4	2	3,234	....	....	.888	.549
May 27 and 28	Tierra Blanca Cañon	+1,162.1	5	3,641	57.0	38.4	.216	.139
	Determined by comparison with camp at mouth Tule Creek:							
June 9 and 10	Camp Scare Spring	+ 905.5	12	3,384	31.8	9.2	26.321	26.397
June 10	Head of water, Tule Creek	+1,053.8	1	3,532	....	....	.187	.259
June 11	Camp Sunday Spring	+ 830.0	9	3,309	15.0	5.0	.622	.474
June 10	Prairie west of Scare Spring	+ 995.3	8	3,474	44.9	15.8	.200	.307
June 9, 11, and 12	Between Scare Spring and cañon	+ 923.9	11	3,403	38.5	11.6	.440	.379

The line of profile here given crossed that of Lieutenant Whipple, Topographical Engineers, on his survey of the thirty-fifth parallel in 1853–'54, near his camp No. 36, on the Canadian River. His camp was higher up than my crossing, and was on the south side of the river, mine being on the north. The two camps were probably only a few miles apart in distance.

	Feet.
Lieutenant Whipple's altitude of his camp No. 36 is given at	2,162.6
The crossing of the Canadian given in my table is	2,402.0
Difference	239.4

The line run to the Canadian River from my permanent camp on Red River touched Lieutenant Whipple's line again near his camp No. 43, and the altitudes are as follows:

	Feet.
Lieutenant Whipple's altitude of his camp No. 43	3,264.6
Camp on Canadian River, May 25, 1876	3,234.0
Difference	30.6

The barometrical readings given in the report of Marcy and McClellan on the survey of the Red River of Texas in 1852 are not at all similar to mine, and, as his altitudes are not calculated, I am unable to suggest the possible reasons for this difference.

BOTANY.

The following list of plants collected during the survey is necessarily an imperfect catalogue of the flora of the country. The collection was made by persons unfamiliar with botany, and generally at the close of a hard day's work, when the leisure hours of camp were utilized in part by gathering specimens of plants at that time in bloom. Besides the numbers of individuals not yet in bloom, and therefore not reported, there were of necessity thus omitted in the list the names of all trees, ferns, and all non-flowering plants. The list is therefore submitted merely for what it is worth of itself.

Upon reaching Fort Leavenworth, Kansas, the collection was placed in the hands of Dr. T. E. Wilcox, Assistant Surgeon, U. S. A., who kindly offered his services. The classification has been prepared by him, and through the kind assistance of Professor Wood, to whom all specimens not recognized were submitted, the list was completed, and Professor Wood's name will be found as the authority in these cases. The list may be considered as almost exclusively one of the flora of the Staked-Plains of Northern Texas.

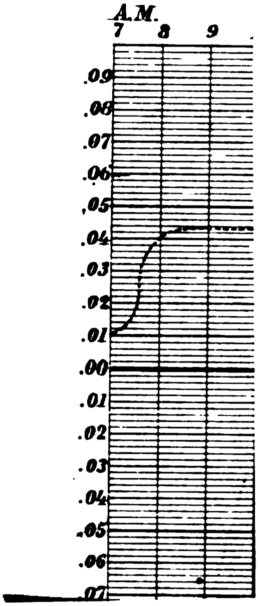
CATALOGUE OF PLANTS COLLECTED IN NORTHWEST TEXAS, NEAR THE HEADWATERS OF RED RIVER, BY FIRST LIEUT. E. H. RUFFNER, U. S. ENGINEERS.

RANUNCULACEÆ.

Anemone Caroliniana, Watt; Torr. and Gr., Fl. 1, p. 12.
Delphinium Azureum, Michæ; Torr. and Gr., Fl. 1, p. 32.
Ranunculus aquatilis, Wood.

PAPAVERACEÆ.

Argemone Mexicana, Linn.; Torr. and Gr., Fl. 1, p. 61.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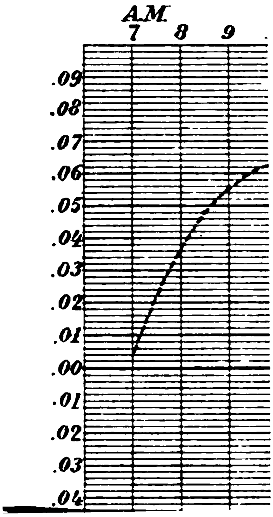
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CRUCIFERÆ.

Vesicaria.
V. Ludoviciana, D. C.
V. Angustifolia, Nutt.; in Torr. and Gr., Fl. 1, p. 101. Gray, Pl. Lindh., p. 145.
Nasturtium sinuatum, Wood.

PORTULACACEÆ.

Talinum Teretifolium, Pursh. Fl. 2, p. 365. Gray, Gen. Ill., t. 98.

MALVACEÆ.

Malvastrum Coccineum, Gray, Gen. Ill., t. 121, pl. Fendl., p. 24.
Malva coccinea, Nutt.
Sida coccinea, D. C., Torr. and Gray, Fl. 1, p. 235.
Callirrhoë involucrato, Gray, Pl. Fendl., p. 15, and Gen. Ill., t. 117.
Malva involucrata, Torr. and Gray, Fl., p. 226.
C. digitata, Nutt., in Jour. Acad. Phil. 2, p, 181; Gray, l. c.
C. Pedata.

LINACEÆ.

Linum Berlandieri, Hook; Brt. Mag., t. 3480; Engelm., in Gray, Pl. Wright 2, p. 25.

OXALIDACEÆ.

Oxalis Violacea, Linn; Torr. and Gray, Fl. 1, p. 211.
O. Stricta, Linn; Torr. and Gr., Fl. 1, c.

ANACARDIACEÆ.

Rhus Trilobata, Nutt. in Torr. and Gr., Fl. 1, p. 218; Gray, Fl. Fendl., p. 28.
R. Toxicodendron, Linn.; Torr. and Gray, l c.

VITACEÆ.

Vitis Rupertis, Sheele in Linnæa, 21, p. 591; Gray, Pl. Lindh. 2, p. 165.

SAPINDACEÆ.

Sapindus Marginatus, Willd.; Torr. and Gr., Fl. 1, p. 255; Gray, Gen. Ill. 2, t. 180.

POLYGALACEÆ.

Polygala Alba, Nutt., Gen. 2, p. 87; Gray, Pl. Wright 1, p. 38; P. Beyrichii, Torr. and Gray, Fl. 1, p. 670.

KRAMERIACEÆ.

Krameria lanceolata, Wood.

LEGUMINOSÆ.

Tephrosia Virginiana, Pers.; Torr. and Gr., Fl. 1, p. 295.
Glycyrrhiza Lepidota, Nutt., Gen. 2, p. 106; Torr. and Gr., Fl. 1, p. 298.
Psoralea
P. Tenuifolia.
Dalea.
D. Formosa.
D. laxiflora, Ph., Wood.
Sophora sericea, Wood.
Petalostemon Violaceus, Michx., Fl. 2, p. 50, t. 37, f. 2; Torr. and Gray, Fl. 1, p. 310.
Petalostemon Gracile, Nutt., in Jour. Acad., Phil. 7, p. 92; Torr. and Gray, Fl. 1, p. 309.
Amorpha Canescens, Nutt, Gen. 2, p. 29; Torr. and Gray, Fl. 1, p. 306.
Astragalus Nuttallianus, D. C., Prodr. 2, p. 289; Torr. and Gr. 2, p. 234.
A. Caryocarpus, Ker. Brt. Reg., t. 176; Torr. and Gr., Fl. 1, p. 231.
A. Gracilis.
Baptisia Australis, R. Br.; Torr. and Gr., Fl. 1, p. 385.
B. Leucophaea, Nutt., Gen. 1, p. 282; Torr. and Gr. l. c.
Desmanthus brachylobus.
Mimosa fragrans, Wood.
Hoffmanseggia Jamesii, Torr. and Gr., Fl. 1, p. 293; Gray, Pl. Lindh. 2, p. 178.

ROSACEÆ.

Sanguisorba Annua, Nutt. in Torr. and Gray, Fl. 1, p. 429.
Poterium Annum, Hook., Fl. Bot. Am. 1, p. 198.
Rosa Blanda, Wood.

ONAGRACEÆ.

Œnothera Rhombipetala, Nutt. in Torr. and Gr., Fl. 1, p. 493; Kunze, in Linnæa., 20, p. 57.
Œ. Sinuata, Linn.; Torr. and Gray, Fl. 1, p. 294.
Œ. Speciosa, Nutt. in Jour. Acad. Phil. 2, p. 119; Torr. and Gray, Fl. l. c.
Œ. Lavandulæfolia, Torr. and Gr., Fl. 1, p. 501; Hooker's Lond. Jour. Brt. 6, p. 223; Gray, Pl. Wright, 1, p. 72.
Œ. Serrulata, Nutt., Gen., 1, p. 246; Torr. and Gray, Fl. 1, p. 501.
B. Oblongifolia, Wood.
Gaura Coccinea, Nutt., Gen. 1, 249; Torr. and Gray, Fl. 1, p. 518.
G. Villosa, Torr., Amer. Lyc., New York, p. 200; Torr. and Gray, Fl. 1, p. 518; Gray, Pl. Wright 1, p. 73.
Œnothera Canisceus, Torr., Wood.
Œnothera Missouriensis, Wood.
Œ. Hartwegii, Bentle., Wood.
Gaura Sinuata, Nutt., Wood.
G. Parviflora, Wood.

COMPOSITÆ.

Solidago Odora, Nutt.; Torr. and Gr., Fl. 2, 219.
S. Missouriensis, Nutt. in Jour. Acad. Phil. 7, p. 32, and Trans. Amer. Phil. Soc. (n. ser.) 7, p. 327; Torr. & Gr., Fl. 2, p. 222.
Artemisia filifolia, Torr. in Amer. Lyc., N. York, 2, p. 211; Torr. and Gr., Fl. 2, p. 417.
Achillea Millefolium, Linn.; Torr. and Gray, Fl. 2, p. 409.
Riddellia Tagetina, Nutt. l. c., p. 371; Torr. and Gr., Fl. 2, p. 362; Torr. in Emory's Rep., t. 5; Gray, Pl. Fendl., p. 93.
Rudbeckia Hirta, Linn.; Torr. and Gr., Fl. 2, p. 307.
Echinacea Angustifolia, D. C., Prodr. 5, p. 554; Torr. and Gr., Fl. 2, p. 306.
Lepachys Columnaris, Torr. and Gr., Fl. 2, p. 315.
Rudbeckia Columnaris, Pursh., Fl. 2, p. 575.
Helianthus Petiolaris, Nutt. in Jour. Phil. 2, p. 115; Sweet Bril., Fl. Gard. (n. ser.) t. 75.
Gaillardia Pulchella, Foug; D. C. Prodr, 5, p. 652; Torr. and Gray, Fl. 2, p. 366.
Englemannia Pinnatifida, Torr. and Gray, in Nutt.. Trans. Am. Phil. Soc. (n. ser.) 7, p. 433; Fl. 2, p. 283.
Crepis Runcinata, T. & G.
Thilespirunum gracile, Gray; *Cosmidium*, T. & G.
Hellienium tenuifolium, N. (but the lower leaves are not entire.)
Lygodesmia juncea, Don.
Melampodium Cinereum, D. C., Prodr, 5, p. 518; Gray, Fl. Fendl., p. 78.
M. ramosissimum, D. C. l. c.; T. & G., Fl. 2, p. 271. *M. leucanthum*, Torr. & Gr., l. c.
Centaurea Americana, Nutt. in Jour. Acad. Phil. 2, p. 117; Bart., Fl. Amer. Sept., t. 50; Torr. & Gr., Fl. 2, p. 453.
Cirsium Undulatum, Spreng.; Torr. and Gray, Fl. 2, p. 456.
Aplopappus Hookerianus, Wood.
Aplopappus Spinulosus, Wood.
Hymenopappus Tenuifolius, Wood.
Townsendia Strigosa, Wood.
Cosmidium Gracile, Wood.
Pyrrhopappus Grandiflorus, Wood.
Melampodium Cinerium, Wood.
Berlandiera Incisa, Wood.
Eclimacea Angustifolia, Wood,
Erigiron tume, Wood.
E. radicatum, Hook, Wood.
Actinella linuariifolia, Wood.
Lygodesmia aphylla, Wood.
Chrysopsis villosa, Wood.
Aplopappus rubiginosus, T. & G. This plant agrees well in all respects with descriptions, but the rays are tinged with *blue*. They should be yellow. What does it mean? Wood.

GENTIANACEÆ.

Erythraea Beyrichi, Torr. and Gr. Fl. 2, ined.

APOCYNACEÆ.

Apocynum Canabinum, Linn.; Hook. Fl. Bar. Amer.; 2, p. 51, t. 139.
A. hypericifolium, Wood.

ASCLEPIADACEÆ.

Asclepias Speciosa, Torr. in Ann. Lyc., 2, p. 218, and in Frémont's first rep., p. 95.
Asclepias tuberosa, Wood.

CHENOPODIACEÆ.

Monolepis chenopodioides, Mog. *B. trifolia*, Wood.

CONVOLVULACEÆ.

Evolvuus Pilosus, Nutt. Gen. p. 174, (as a synonym;) Trans. Amer. Phil. Soc. (n. ser.) 5, p. 195.
Convolvulus Lobatus, Engelm. and Gray, 1 Pl. Lindh. p. 44, (in a note.)
C. hastatus, Nutt. in Trans. Amer. Phil. Soc. (n. ser.) 5, p. 194, not of Thumb.
C. Nuttallii, Torr. in Emory's Rep., p. 149.
Ipomea leptophylla, Torr.; Wood.

SOLANACEÆ.

Physalis Pumila, Nutt. in Trans. Amer. Phil. Soc. (n. ser.) 5, p. 193.
Solanum Mexicanum, Wood.
Physalis lobata, Torr. Wood.

RHAMNEÆ.

Ceanothus Americanus, Wood.
C. Ovalis, Wood.

SCROPHULARIACEÆ.

Pentstemon acuminatus, Doug.; Wood.
Veronica Peregina, L.; Wood.
Pentstemon Cœruleus, Wood.

ACANTHACEÆ.

Ruellia stripens, Wood.

LABIATÆ.

Monardà Aristata, Nutt. in Trans. Amer. Soc. (n. ser.) 5, p. 186. Benth. in D. C. Prodr. 12, p. 363.
Scutellaria Resinosa, Torr. in Ann. Lyc. N. York, 2. p. 232. Benth. in D. C. Prodr. 12, p. 427.

VERBENACEAE.

Lippia Cuneifolia, Torr., in Ann. Lyc. N. York, 2 p. 234.
Lippia lanceolata, Wood.
Verbena Bipinnatifida, Engelm. and Gray, Pl. Lindh. i, p. 49; Shauer, D. C., Prodr. ii, p. 553.
Verbena erinoides. Wood.

BORAGINACEÆ.

Eritrichium Jamesii, *Myosotis suffruticosa*, Torr., in Amer. Lyc. N. York, 2, p. 225, D. C. Prodr. 10, p. 114.
Phacelia integrifolia, Torr.
Echinospermum Lappula, Wood.
Lithospermum longiflorum, Wood.

CUPULIFERÆ.

Quercus Undulata, Torr., in Ann. Lyc. 2, p. 248, t. 4.

GNETACEÆ.

Ephedra antisiphilitica, Meyer, (without flowers or fruit,) Wood.

CONIFERÆ.

Juniperus Virginiana, Lin., Michx. f. Sylv. 2, p. 353, t. 155; Torr., Fl., N. York, 2, p. 235.

COMMELYNACEÆ.

Tradescantia Virginica, Linn., Brt. Mag., t. 105, Bart. I, o. t. 141. Kunth. Enum. 4, p. 81. Torr. Fl., N. York, 2, p. 333.

IRIDACEÆ.

Sisyrinchium Bermudianum, Linn., Torr., Fl., N. York, 2, p. 290.
Nemastylis acuta.

LILIACEÆ.

Allium reticulatum.

CYPERACEÆ.

Carex Muhlenbergii, Schk. Car. 2, p. 12, f. 178.. Schwein and Torr. Car., p. 304. Torr. Fl., N. York, 2, p. 394.
Carex lanuginosa, Wood.
Carex disjuncta, Wood, allied to *C. conjuncta*, Boott.
Scirpus pungens, Wood.
Eleocharis olivacea, Wood.

EQUISETACEÆ.

Equisetum Hyemale, Linn. Pursh., Fl. 2, p. 652. Forr., Fl., N. York, 2, p. 482.
Equisetum Levigatum, Wood.

FILICES.

Adiantum Capillus Veneris, Wood.

GRAMINEÆ.

Uniola Latifolia, Michx. Fl. 1, p. 71. Ell. Sk. 1, p. 167 Kunth. Enum. 1, p. 425.
Poa Andina, (an imperfect specimen,) Wood.
Poa Michauxii, Kunth., Wood.
Hordeum jubatum, Wood.
Triticum repens, L. (? No root or leaves,) Wood
Poa Compressa, Wood.
Andropagon argenteum, Wood.
Festuca tenella, Wood.
Aristida purpurea, Wood.
Eatonia obtusata, Gr., Wood.
Tricuspis acuminata, Moma., Wood.
Elymus Sitanion, Schutt., Wood.
Elymus Virginicus B. *vaginatus*, a dwarf form 3-6 feet high spikes sheathed, Wood.

NYCTAGINACEÆ.

Allionia incarnata, L.
Oxybaphus angustifolius, Sweet., Wood.

POLEMONIACEÆ.

Gillia filifolia, Nutt.

PLANTAGENACEÆ.

Plantago Patagonica, Torr.
Stenosiphon virgatus ?

REPORT OF LIEUTENANT THOMAS M. WOODRUFF, FIFTH INFANTRY.

FORT LEAVENWORTH, KANSAS, *February* 1, 1877.

SIR: I have the honor to submit the following report on the insects collected by me during the exploration and survey of the headwaters of the Red River of Texas, in 1876:

My implements were very incomplete, and those I had were hurriedly constructed. They consisted of three nets which could be fastened to the end of a long pole, a couple of killing boxes, and two collecting boxes. These boxes were tin baking-powder boxes of different sizes. I also had two sets of trays or drawers, sixteen dozen pill-boxes in nests, raw cotton, long sharp-pointed pins, some glass bottles, and a pair of steel pliers. For killing and preserving the specimens, I used cyanide of potassium, chloroform, arsenic in solution, and alcohol. As far as my limited knowledge extended, I arranged the specimens under their general classes, and in every case I gave date and locality of capture. In doing the former, I was guided by Dr. A. S. Packard's pamphlets on the directions for collecting and preserving insects. I regret, however, that I had so little knowledge on the subject, for I lost many interesting facts concerning the habits of many of the specimens, and also failed to note many well-known species. In order to have the specimens properly classified, they were sent to Mr. Herman Strecker, of the Reading Society of Natural Sciences, to whose list I respectfully refer you. He finds about 126 different species.

I am greatly indebted to the officers and the men of the expedition for collecting many interesting and valuable specimens.

I am, sir, very respectfully, your obedient servant,

THOS. M. WOODRUFF,
Lieutenant Fifth Infantry.

Lieut. E. H. RUFFNER,
Corps of Engineers, Chief Engineer, Department of the Missouri.

CLASSIFIED LIST OF INSECTS BY MR. HERMAN STRECKER.

READING SOCIETY NATURAL SCIENCES,
Reading, Pa., November 9, 1876.

SIR: I herewith transmit a classified list of the insects forwarded to us in September last, which were collected by the expedition under your charge during the surveys and explorations of the region of the headwaters of the Red River of Texas, in May and June, 1876.

The general area from which the collection was made, was that parts of the "Llano Estacado," or Staked Plains of Texas, embraced between longitude 100° 30′ west to 102° west, and latitude 34° to 35° 30′.

My thanks are due to Messrs. Charles A. Blake and E. T. Cresson for aid in determining the Hymenoptera, to Mr. A. S. Fuller in the Coleoptera, and to Dr. Cyrus Thomas in the Orthoptera.

Very respectfully, yours, truly,

HERMAN STRECKER.

Lieut. E. H. RUFFNER,
Corps of Engineers, Chief Engineer, Department of the Missouri.

HYMENOPTERA.

CHRYSIDIDÆ.

Chrysis Clara, Cress., 1 ♀.

LARRIDÆ.

Larrada semirufa, Cress., 1.
Tachytes abdominalis, Say, 1.

SPHEGIDÆ.

Chlorion cæruleum, Dru., 1 ♂.

POMPILIDÆ.

Pompilus Aethiops, Cress., 3 ♂.
Pompilus tenebrosus, Cress., 1 ♀.
Priocnemis validus, Cress., 1 ♀.
Pepsis marginata, Beau., 2 ♀.

MUTILLIDÆ.

Mutilla californica, Rad., 3 ♀.
Mutilla fenestrata, St. Farg., 3 ♂.
Mutilla ferrugata, Cress., 1 ♂.
Mutilla Fulvohirta, Cress., 1 ♂.
Mutilla gorgon, Blake, 2 ♂.
Mutilla orcus, Cress., 1 ♀.
Mutilla oajaca, Blake, 1 ♂.
Mutilla Sayi, Blake, 1 ♂ var.
Mutilla simillima, Smith, 2 ♀.
Mutilla zelaya, Blake, 1 ♂.
Agama castanea, Cress., 1 ♂.
Agama tapajos, Blake, 1 ♂ var.

VESPIDÆ.

Polistes minor, Cress., 3 ♀.
Polistes texana, Cress., 11 ♀.

ANDRENIDÆ.

Augochlora fervida, Smith, 1 ♀.
Eunomia marginipepennis, Cress., 1 ♂.

APIDÆ.

Megachile gentilis, Cress., 1 ♂.
Mellissodes australis, Cress., 1 ♀.
Mellissodes menachus, Cress., 1 ♂.
Anthophora occidentalis, Cress., 1 ♀.
Bombus nevadensis, Cress., 1 ♀.
Bombus pennsylvanicus, De Geer, 3 ♀, 4 ☿.

LEPIDOPTERA.

RHOPALOCERA.

PAPILIONIDÆ.

Papilio asterius, Cram, 1 ♀. Tule Creek.

Differs from the normal ♀ form in the total obsolescence of the submarginal row of yellow spots on both the upper and under surfaces of primaries.

PIERIDÆ.

Pieris protodice, Bdl. et Lec., 2 ♂; one from Tule Creek, the other from Salt Fork.
Colias eurytheme, Bdl., 1 ♂ from Cañoncito Blanco, 1 ♀ normal, and 1 ♀ albino from Mulberry Creek.
Meganostoma cæsonia, Stoll, 1 ♂. Cañoncito Blanco.
These *Pieridæ* present no points of difference from those found in various other localities in the United States and Territories.

LYCAENIDÆ.

Thecla mopsus, Hubn., 1 ♂ 1 ♀. Tule Creek.
Lycæna melissa, W. H. Edwards, 1 ♀. Tule Creek.

NYMPHALIDÆ.

Euptoieta claudia, Cram.
Argynnis Columbina, Godt., 2 ♂ 1 ♀. Mulberry Creek.
One ♂, head of Red River, rather small, otherwise not peculiar.
Eresia Carlota, Reak, 1 ♀. Head of Red River.
Eresia Tharos, Dru., 1 ♂. Head of Red River.
Apartura celtis, Bdl. et Lec., 2 ♀ var. Tule Creek.
Both expand 2¼ inches. They are of much the same reddish or tawny hue as the variety described by W. H. Edwards under the name of *Alicia*, but the outer half of the

primaries is not blackish brown as in that form, but is reddish, with some slight pale-brown shading, differing but little from the ground color of the rest of the upper surface. The most noteworthy point of distinction in the example is, however, in the presence of another ocellus on primaries, situated in cell 3 in a line with the one in cell 2, the two being of like size; nor are they larger than the largest one of the six on the inferiors; both have a large white pupil; beneath they are larger and are ringed with yellow, and also pupilled with white. This description applies to both examples, except that the other has in cell 4 also an ocellus, making a submarginal row of four ocelli on superiors. This ocellus in cell 4 has a much larger white pupil than either of the other three, though on the whole it is smaller than the two in cells 2 and 3 and the same size as its partner in cell 5. The ocelli on upper surface of secondaries have bluish white or gray pupils. These two examples are by far the most interesting of the Lepidopterous insects taken.

DANAIDÆ.

Danais plexippus, Lin., 4 ♂.
This species occurred in every locality visited by the expedition.
Danais Berenice, Cram, 1 ♀. Tule Creek.

HESPERIDÆ.

Pamphila iowa, Scud., 4 ♂. Tule Creek.
Pamphila ottoe, W. H. Edwards, 1 ♂, 1 ♀. Mulberry Creek.
Ægiale cofaqui, Streck., 1 ♀. Tule Creek.
Is of much greater size than the type from which the species was recently described, (in Proc. Acad. Nat. Sci. Phil.,) expanding fully three inches. It has also one more white spot, (situated somewhat toward the apex or under side of secondaries.) The sub-apical marks in primaries are also larger than is the type. I have adopted Felder's generic name as having priority over *Megathymus* of Scudder.

HETEROCERA.

ZYGAENIDAE.

Alypia octomaculata, Fabr., 1 ♀. Mulberry Creek.

SPHINGIDAE.

Deilephila lineata, Fabr. 1, larva.
Sphinx lugens, Wlk., 1 ♂. Salt Fork.

NOCTUIDÆ.

Hadena inordinata, Morrison, 1 ♂. Head of Red River.
Syneda ingeniculata, Morrison, 1 ♀. Cañoncito Blanco.
Bolina deducta, Morrison, 1 ♀. Salt Fork.

DIPTERA.

Tabanus atratus, Fabr.
Sarcophaga carnaria, Linn.
Tachina,———? Figure 18 on plate V of Glover's "Illustrations of insects Diptera," but without being named.
Lucilia Cæsar, Linn.

COLEOPTERA.

CINCINDELIDÆ.

Amblycheila cylindriformis, Say, 2 examples.
Cincindela pulchra, Say, 3.
Cincindela scutellaris, Say, 1.
Cincindela tranguebarica, Hübn, 1.
Cincindela punctulata, Fabr., 1.

CARABIDÆ.

Pasimachus elongatus, Lec., 1.
Ebarthus incisus, Lec., 7.
Harpalus calignosus, Fabr., 2.
Harpalus pennsylvanicus, Deg., 1.
Chlœnius tomentosus, Say, 1.
Cymindes abstrusa, Lec., 1.
Helluomorpha, texana, Lec., 1.

HYDROPHILIDÆ.

Hydrophilus triangularis, Say, 1.

STAPHYLINIDÆ.

Creophilus villosus, Grav., 2.

DERMESTIDÆ.

Dermestes lardarius, Lin.
Dermestes marmoratus, Say, abundant.

COCCINELLIDÆ.

Hippodamia glacialis, Fabr.
Cyclonida abdominalis, Say.

HISTERIDÆ.

Saprinus oregonensis, Lec.

SCARABÆIDÆ.

Phanaeus carnifex, Lin., 1 ♂.
Trox suverosus, Fabr., 2.
Canthon hudsonias, Forst, 1.
Lachnosterna glabricula, Lec., 1.
Iostegoptera lanceolata, Lec., 1 ♂.
Anomala binotata, Gyll., 2.
Strigoderma arboricola, Fabr., 1.
Euryomia Kernii, Hald., very abundant and in many varieties.

BUPRESTIDÆ.

Melanophila miranda, Lec., 1.
Chrysobothris femorata, Fabr., 1.

ELATERIDÆ.

Lacon rectangularis, Say, 3.

LAMPYRIDÆ.

Photuris pennsylvanicus, De G., 1.

CLERIDÆ.

Thanasomus spinolai, Lec., 2.

CERAMBICIDÆ.

Batyle ignicollis, Say, 3.
Batyle suturalis, Say, 2.
Typocerus cinnatus, Neum., in great numbers.
Mecas inornati, Say, 1.
Moneilema anulatum, Say, 3.

CHRYSOMELIDÆ.

Chrysomela exclaimationis, Rog., 1.
Plagiodera confluens, Rog., 2.

TENEBRIONIDÆ.

Eleodes sponsa, Lec., 2.
Eleodes tricostata, Say, 3.
Eleodes obsoleta, Say, 2.
Eleodes extricata, Say, 2.
Eleodes acuta, Say, 1.

MELOIDÆ.

Macrobasis imaculata, Say, 6.
Macrobasis segmentata, Say, 3.
Epicauta ferruginea, Say, 5.
Nemognatha lurida, Lec., many examples.
Nemognatha discolor, Lec., 3.
Gnathium minimum, Say, 1.
Oxacis canna, Lec., 1.

CURCULIONIDÆ.

Sphenophorus 13-punctatus, Ill., 4.

HEMIPTERA.

Galgulus oculatus, Fabr., 1.
Brochymena arborea, Say, 5.
Strachia histrionicha, Hahn., 2.
Leptoglossus phyllopus, Lin., 7.
Apiomerus spissipes, Say, 2.

ORTHOPTERA.

GRYLLIDÆ.

Gryllus abbreviatus, Serv., 1 ♀, 3 pupæ.

LOCUSTRARIÆ.

Udeopsylla robusta, Scud., 3 ♂.

ACRIDII.

Caloptenus bivittatus, Uhler., 1, pupa.
Hesperotettix viridis, Thos., 2 ♂, 3 ♀, 1 pupa.
Œdipoda corallipes, Hald., 2 ♂, also pupa of either this or the allied *Œdipoda discoidea*, Serv.
Trimerotropis citrina?, 1 ♂.

In reference to this example Dr. Thomas says: "I am not positive; it is possible that it belongs to *T. vinculata*, a very closely allied and scarcely distinct species."

Tragocephala pacifica, 1 ♂.
Acrolophitus hirtipes, 2 larvæ.

BLATTARIÆ.

Ischnoptera unicolor?, 3 ♂, 2 ♀.

NEUROPTERA.

LIBELLULIDÆ.

Æschna heros, Fabr., 3.
Libellula trimaculata, De G., 2.

GEOLOGICAL NOTES.

The Staked Plains of Texas, wherein are found the sources of the Red River, present features favorable to geological research in the fine sections exhibited in the various cañons made by the different streams. To the student who visits these places, the first view seems fraught with promise of glorious results. Strata, vivid in color and various in composition, lie clear cut in sheer cliffs before his eyes, and invite a study made easy. And as he passes from one cañon to another, and

finds the whole country seamed by the net-work, the fortuitous labor of nature appears almost supererogatory. Standing by the brink he sees the solemn front of the huge mesa break down at the edges, and a mass of rolling or abrupt and rough hills succeed the ceaseless long, gentle swell of the plains' surface proper, and the field for study increases and swells to vastness. But the reality is a disappointment. The rolling swell of the general surface is participated in by the underlying rocks, and cañon after cañon throughout their whole extent present in general but the same section, different only as the erosion has been greater, or from slight local causes. So the grand walls of the grand cañon, with their brilliant cliffs and spires, their castellated hills and cathedral ruins, red, and red, and red, are again encountered in the smaller tributaries, until the red sandstone goes under the surface, and the chalky tops of the cañon walls are found from one to the other until they too disappear, the very water-courses cease to be, and the unbroken prairie reigns supreme.

Again the series of strata which do form the field for study are vaguely coarse and unattractive, upon close inspection, and the absence of fossil life makes their stony pages almost the blank leaves of nature's volume, unless, perhaps, they are instead the highly decorated pages of her book of illustrations only.

One thing, however, can be read everywhere, and that is the effects of aqueous power on a grand scale—commensurate with the boundless area at nature's disposal when forming these fields to her taste. The section which is here presented will describe the country between longitude 101° and 102° west from Greenwich, and between latitude 34° 30′ north and latitude 35°, or about 60 miles east and west, and 30 north and south. As I shall point out, the same, or a similar section, may be expected through the whole region from this to Dodge City, or on a line running a little east of north.

The thickness of the various strata varies at points, but not to any great extent, and within the region as given I have myself verified the general section at nearly every point, certainly at places within sight of one another, and so situated that no serious difference could occur.

I shall commence at the top, and describe the series in descending order.

The general surface of the plains is gently undulating, and sometimes in such great swells as to present all the appearance of distant hills or mountains, even, when magnified by the mirage and with the heightened illusion of the level, where, with nothing to serve as a comparison, the judgment often fails to locate the distance. A noticeable instance of this swell and depression, this wave and its trough, occurs at the head of the main cañon, where a north and south wave has made a trough, and the swell of which is cut through in the minor cañons of the Palo Duro and the Tierra Blanca, 10 miles to the west of this. Again the bluffs of the cañon of the southern stream rise up to the traveler from the north.

At the permanent camp, 8 miles east of the head of the main cañon, the drift and alluvium may have been 75 feet in thickness, and at Cañoncito Blanco this thickness may have been equal or less. The drift is fine and gravelly, or at times sandy, though never enough so to make the roads troublesome; the surface is almost always hard.

No. 1. Drift, 75 feet.

Near the Tule Cañon, farther to the south, the drift sometimes entirely disappears, or is found only in the side arroyas or drainage channels, and the chalky limestone of No. 2 is found frequently exposed on

the level surface of the plains, while the outcrop near the cañons almost precludes the existence of drift above.

No. 2 is a chalky limestone, very friable and weathering into minute fragments, with rectangular joints. No fossils were found, and it was difficult at any time to get access to the limestone stratum, so extensive was the disintegration. This number was seen at every place where the summit of the general level was met, and was last seen at Bluff Creek, near Fort Dodge, and on the prairie between that point and the Arkansas River. It will be noted that the altitude of Dodge City is about that of Fort Elliott, and the line joining the same may be considered a strike line of the section under description.

No. 2. Chalky limestone, 75 to 100 feet.

No. 3 is a layer of compact limestone, almost marble, of smooth grain, but concboidal in fracture, and inclined to break into small rectangular fragments. This seems to contain no fossils though very carefully examined for such. It is very firm and porphyritic in appearance, with whitish blots. The color is white or light gray, sometimes with a pinkish tinge in the sunlight. It will be seen as the upper decided outcrop in the views given of all the cañons. It is the upper water-bearing rock, and when it disappears under the surface at the head of the Palo Duro, Tierra Blanca, Tule, and Cañoncito Blanco, there will be found the head of water. It and the number just above it seem to be quite insoluble, as the water of these springs is singularly sweet and pure. This rock is used in the construction of Fort Elliott, where it is burnt for lime, and where its small and convenient size at the quarry makes it suitable for the foundations of the light frame-houses of that post. At this point it is not far distant to the north in a spur of the plains which pushes to the east, and is the divide between the Washita and the North Fork of Red River. This number was not noticed again unless, perhaps, in the high land between the heads of Bear Creek and Bluff Creek in Kansas.

No. 3. Compact limestone, 5 to 10 feet.

No. 4 is a clay, sometimes sandy, sometimes gravelly, but never stone, although very compact. This presents curious features. On the Red River and the Palo Duro and Tierra Blanca, on the margin of the cañon wall were found at places immense quantities of calcified and silicified (sometimes) roots which seemed the stratum in all directions. Trunks and butts of trees were found above in No. 3. So extensive was the calcified fibrous character at times, that the appearance was almost that of a coral bed. In other cañons this feature seemed lacking in this number, and from the fact that upon excavating into the bank, the roots were thought to diminish in quantity and lessen in size as the bank was entered, it appeared likely that the trees were located then, as now, on the margin of a water-course. No fossil-leaves were found; nothing but the petrified wood so generally reported upon by every traveler in these parts. The formation of this number seems to have been quite rapid from the evenly smooth character and from the fact that pockets of sand and gravel were found in considerable quantity resting upon the next lower number. These pockets evidently belonged to the number under description, and were formed by the sifting and settling of their contents through the lighter mud of the upper part. In these pockets were discovered the first fossils. At the Cañoncito Blanco, wherever exposed, shells could be found by a little search, but no shells were found in this number except in these pockets. The shells were all lamellibranchs, and were abundant in number, but of few varieties. I have spoken more in detail of them in another place. All were more or less water-worn, and appeared in general to have been brought or

No. 4. Clay sometimes sandy, sometimes gravelly, 75 to 100 feet.

washed there, rather than to have been left by their wearers. At no other place were the shells so abundant as in Cañoncito Blanco, though a few were found in the Tule and in Mulberry Creek.

No. 5. Sandstone conglomerate, 6 to 20 feet.

No. 5 is a sandstone conglomerate, compact in texture but easily worn by water or weather. The gravel found in it is small and is not very abundant. A few fossils were found and even occasional pockets. Generally, however, the conglomerate was quite free from shells.

No. 6. Red sandstone shales and clays, 75 to 100 feet.

No. 6 consisted of from 75 to 100 feet of red sandstones or clays sometimes passing into shales. Occasionally were beds of white, shaly sandstones, and sometimes almost clear sand or even partially conglomerate. Very few shells were found, but these were believed to have different varieties than those of the upper number, the difference being, perhaps, in Ostræa. This number varies very much, running through all the varieties of sand and clay and their rocks. Shales are light-colored or red, or sometimes dark, and in these shales are found springs at several points. The number also varies considerably in thickness and in many places gives less than the minimum here quoted.

No. 7. Hard sandstone, 15 to 50 feet.

No. 7 is a hard dark-colored sandstone withstanding both water and weather. It is heavy and compact, and by its resistance it forms the second check in the formation of the cañons, the upper limestone being the first. The main falls of the Red River are formed by this layer, and the narrow gulley or trench described as cut in the rock below the falls could have been possible only in this number. These falls, 25 or 30 feet high, are reproduced in the Cañoncito Blanco by the same stratum and at a less height, and again in the Tule Cañon are found the same. Its firmness and dark color make it bold in relief and in appearance wherever the cañon-walls are precipitous. Occasional pebbles and gravels are found, but no fossils have been noted. This rock supports the last of the good water in descending order, and springs or running water found lower than this will be apt to be alkaline. We have thus far described a section from 325 to 455 feet in depth, and as yet the gypsum has not been encountered. Moreover the characteristics of the numbers already specified are quite distinct and are easily recognized. The main cañon cuts fully 12 miles of its course before these are passed through, and our camping places on the Mulberry, the Salt Fork, the Upper McClellan Creek, and the Big Spring on North Fork, as well as Fort Elliott itself, and the creek at which it is supplied with water, are all found within the limits of so much of the section.

On ascending the divide from Bear Creek, Kansas; that is, in passing out of the valley of the Cimarron, we also pass through the lower of these numbers, and there are outcrops of conglomerate and sandstone, containing not only the same fossils already obtained and alluded to, but many others of similar varieties. Many specimens of the *Ostræa Pastina* are found in good condition and very little water-worn. It appeared to me that much the same varieties were obtained at Bear Creek that were collected on the divide between Beaver Creek and Sand Creek just north of Camp Supply, and that, in addition thereto, the small shells of Cañoncito Blanco were added, which were not found, certainly in numbers, at the outcrop near Camp Supply. It bore every appearance that the formation at Bear Creek was contemporaneous with that of the lower portion of the section, as so far described, and that the more-finely comminuted elements of the Staked Plains, the water-worn specimens, the less number of varieties, and the smaller shells, all indicated

that Bear Creek was nearer the edge of the cretaceous ocean at that time, and that the Red River country was probably in deep and quiet water. I might add that no bowlders, or even large gravel, are found in the Red River country in the conglomerates of the whole section.

It is difficult to separate the lowest number into distinct and definite individuals. A confused mass of red sandstones and clays or shales are found as low as the cañon-walls extend. Where the sandstones predominate, as in the Tule Cañon, a massive and striking cliff of brilliant red, 200 feet and more in height, rises sheer from the stream. When the clays are in excess, or clays and shales or slates, the weird castles and churches, and brilliant mockeries of the Red River itself are seen. In this number the occasional or at times more numerous or thicker beds or layers of gypsum are found. The gypsum is not found above No. 7. The gypsum deposits are scattering and varied in importance as well as in colors. All water found flowing beneath the lower surface of No. 7 is apt to be tainted, and no exception of a fresh, sweet spring was found. There may be light-colored sandstones, and, at times, limestones in beds or thin layers may be seen. Occasionally a bluish tint is found in the shales. The gypsum is generally white or light-colored; but all colors are overwhelmed with the general vivid red of the whole land. Beds of conglomerates are seen, and from one such a few of the small shells of the same varieties, as in Cañoncito Blanco, were obtained. This was located not far from Camp Cent, and probably 8 miles north of Tule Cañon. A few of the same were also seen in position not far from D Company Creek camp. It seems hardly necessary to dwell on the peculiarities of this region, so often and well described.

No. 8. Sandstones, shales, and clays, 700 feet and more.

It seemed worthy of remark, however, that the barometer confirmed my own conclusions while on the line of march. The mouth of Tule Creek and the camp on Sand Creek, 9 miles north of Camp Supply, are about at the same altitude, and they have nearly, if not quite, the same geological altitude. The water of Sand Creek is nearly, if not quite, as disagreeable as that of the Tule. Camp Supply is on a higher level and the water is somewhat better, though, I think, quite disagreeable. In crossing the divide between the Beaver and Sand Creeks, the top layer is a conglomerate cemented by lime, with a great abundance of shells of various varieties. I think this is of the same age as the layer spoken of as near the Camp Cent Cañon. These shells were not much water-worn, and were in very great abundance, more so than at any other point visited on the trip.

The vivid gullies and arroyas and vistas seen from the summit of this divide, as one looks to the north down the washed slopes, are as attractive as many views in the cañon 150 miles to the south. Gypsum outcrops are met with between this and the Cimarron, which stream again exhibits the characteristics of the gypsum formation. The rise from this up the bluffs of Bear Creek brings us out of the region again to more pleasant surroundings.

The profile shown by the barometer is one of general level to the north and south, and a long easy slope from the west to the east. The upper level is well preserved, and reappears in detached portions as far as the Antelope Hills on the south of the Canadian and east of the one-hundredth meridian. The east and west streams have cut much the same kind of channels, and the side streams are all constructed in the same fashion. So long as the upper limestone remained in situ the first difficulties were great; but, as is shown by the shapes of the denudation, the climate has in general been mild and much the same as now, the

rains moderate, and the only effects of unusual powers are shown in the commencement of the formation of the cañons. The easy roll of the ground gave inequalities to the surface which formed ponds and lakes. To-day are many basins of size enough to be called small lakes. Filled by the rain, they sometimes are of a depth as great as 10 feet, and many are seen filled every year to a depth of 2, 3, or 4 feet. The largest of these lakes in times past found its outlet over its rim in a small stream which wore away the hard limestone by degrees. At length the time came when this stratum was entirely gone, and the softer material below disappearing rapidly, an extra rainfall, perhaps, carried the small fall of exit for the lake back to its brim, and the large mass of water was set in motion. Tearing down its outlet, the sand, shales and clays were swept away; the unsupported upper layers caved into the channel, and were also carried off by the rush; the wild torrent now with its great fall and huge volume tore its way through the harder sandstone below, and the sharp-cut heads of each cañon were made at one great effort. The lake disappeared, the cañon-walls were gradually shaped by the rains, but not very much, and the network of these water-courses extended backward toward the head of the stream, as the additional height given by the scouring out of the lower channels made the outbreak of the upper lakes more effective and more easily begun. As each fresh torrent tore down the main stream it lent its effort to alter the shape of its bed. Sometimes it widened it, sometimes it cut a new channel, leaving the bed of the former stream to one side and at a higher level to be cut up into valleys and gullies afterwards. As soon as the main work was done the power was exhausted. The light fall of rain was never enough to smooth down and round the sharp-cut walls into gentle slopes of quiet hills, and the formation of soil was impossible for this reason. The absence of soil and rain prevented the accumulation of vegetable life, especially trees, and the whole part of the country since its elevation above the level of the cretaceous sea appears to have been that of a lake region with a scant neighboring flora, small outlets bordered by trees, a cataclysm—perhaps covering some few years—of cañon formation; and the same quiet life of to-day ever since that time. The small stream going down the main cañon has only cut a few hundred yards backward through the sandstone at the falls, and this work might easily have been done in hundreds of years by the present stream.

There are definite bounds now visible to the ancient lakes which formed the main cañon, that of Cañoncito Blanco and the Tule. The evidences are also patent of a similar origin to the Mulberry Creek Cañon.

In the geological report of Lieutenant Whipple's Report, vol. III, Pacific Railroad Surveys, the Antelope Hills are described as having "white limestone" for some of the upper beds. To the west of this point, between the Washita and the Canadian, were found fossil *Ostracea* in a limestone 5 feet thick, and of a whitish gray color. (P. 19.) "The only representation of this formation found in the collection is the well-known cretaceous fossil "*Gryphæa Pitcheri*." The sections given on pages 24 and 25 represent the edges of the Staked Plains, and are all described as having "white limestone" for the upper rock, in one case giving 10 feet for the thickness. Underneath this is given "calcareous conglomerate," "sandstones and marls," and "yellow limestone, with bluish-gray beds, at the bottom containing *Ostræa* ———[?]"

The last section quoted is of Mount Tucumcari, in the valley of the Canadian, about longitude 103° 40′ west, or more than 50 miles beyond my farthest western point. These sections and descriptions are much

more in accordance with my own than those recorded in Marcy and McClellan's report on the Red River, and confirm me in my belief that the geology of the northern part of the pan-handle of Texas, and extending some distance north into the Indian Territory, is one and the same.

The fossils which were brought back were sent to Prof. O. C. Marsh for identification, he having kindly promised to do this as a labor of love. He has not as yet sent me the list, but I hope it may be received in time to be printed with this report. I have endeavored myself, with the slight sources of comparison at my disposal, to classify or describe some of those brought back. By far the greatest number of specimens obtained at the Cañoncito Blanco and in the cañon wherever found consisted of *Ostrœa*. The varieties figured in Meek's report on Cretaceous Invertebrata, United States Geological Survey of the Territories, as the *Ostrœa Patina. Var. A, B, and C* are well represented, in especial the latter named. As I lay no claims to being an expert in palæontology, I may be pardoned if I state that these figures and those of the *Gryphœa Pitcheri*, as given in Vol. II, Pacific Railroad Reports, seem to me to run the one into the other, and that it might be difficult to say at times whether an individual should belong to one or another of the four names quoted. At any rate, whether right or wrong in this, I am certain that I have specimens which exactly represent all the plates and varieties given and drawn in the volumes cited.

The next most prominent fossil in point of numbers I have concluded to be the *Ostrœa Glabra*, (p. 509 Meek.) The fossil so named occurs in great quantity and of all sizes from 1 to 2 inches in length. In addition to these I have found, I think, specimens of the *Ostrœa inornata*, Meek, p. 14; *Mactra* (*Cymbophora*) *Alta*, 210 Meek; *Callista Pellucida*, 187 Meek; *Protocardia Para*, 176 Meek. I have tried to make myself believe that among the specimens collected there were also exhibited *Ostrœa congesta*, *Inoceramus problematicus*, or indeed any variety of *Inoceramus*, but I failed, and at present I do not believe these varieties were found. It so happens that the fossils named so far are located in No. 4, No. 5, and upward of Hayden & Meek section of the cretaceous rocks of the Northwest. I am not familiar with the appearance of this section as described, nor have I seen the upper numbers as quoted in the various reports of the Upper Missouri. It also happens that many of the fossils quoted in the general section as characteristic were not found by myself, and it is again worthy of remark that if the Staked Plains section does belong to the upper rocks of the cretaceous period the colors and general appearances of Nos. 4 and 5 will not fairly describe the southern rocks. Professor Hayden describes the northern lands as dark and somber, and no mention of red is made above the Dakota group. The fossils of the Fort Benton group, as figured, are certainly *not* characteristic of the Staked Plains, and without attempting to place these strata, I merely desire to call attention to these points, and to note particularly the force of my observation, that all the fossils so far named are much *water-worn* and generally small in size, and must have been brought some distance.

The fossils found at Camp Supply are very abundant, and some portions of the rock seem entirely composed of them. The varieties of *Ostrœa* quoted are found, and I thought I could safely call two or three specimens *Inoceramus*. Many and interesting individuals of *Scaphites* were noted and were all well marked and very little water-worn. *Scaphites Conradii* was noted, and it is believed *Scaphites Nodosus*, *Phola-*

domya (*Procardia*) *Hodgii*, Meek, p. 219, was marked as one example, though others were thought to have been possibly the same.

Many specimens of *scaphites* of different varieties were recognized, and a much convoluted shell was thought to be a portion of an ammonite. A strongly-marked bivalve, of beautiful shape and well preserved, awaits recognition, and there are many other varieties which it is hoped will be classified in time.

Perhaps it would be proper at this point to say that at the heads of the various streams, and sometimes in accumulated beds in the lower parts of their courses, and in the ponds on the prairie, were found shells of land and fresh-water varieties of *Physæ*, *Limnæa*, *Planorbis*, and *Unios*. These were not found alive, perhaps because no search was made for them, but I recollect that the head of the Paloduro was in especial marked by great quantities of these shells.

REPTILES.

The party did not attempt to make a full collection of the reptilia. The full and well-illustrated report on this subject in Marcy and McClellan's report seems to have about covered the entire ground, at least to one not a specialist. A few specimens collected were sent to the Reading Society of Natural Sciences, and the accompanying letter gives the list of all specimens so sent.

It may be said, however, that all such belong to species which are abundantly represented everywhere along the line of the survey.

LIST OF REPTILES PREPARED BY DR. M. A. RHOADS.

READING SOCIETY OF NATURAL SCIENCES,
Reading, Pa., December 22, 1876.

SIR: I have the honor to transmit the following list of reptiles forwarded to the society, which were collected by the expedition under your charge during the surveys of the region of the head-waters of the Red River of Texas, in May and June, 1876.

Very respectfully,

M. A. RHOADS, M. D.

Lieut. E. H. RUFFNER,
Corps of Engineers, Chief Engineer Department of the Missouri.

Order SAURIA. Genus CROTOPHYTUS.

Crotophytus Collaris, Holbrook.

Genus TAPAYA.

Tapaya Douglasii, G.

Order OPHIDIA. Genus CROTALUS.

Crotalus ledamantus, Beauv.
Crotalus Confluentus, Say.

Genus HETERODON.

Heterodon Nasicus.

Also along with the above—
Mygale Hentzii.

APPENDIX S S.

ANNUAL REPORT OF CAPTAIN JAMES F. GREGORY, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF TEXAS.

HEADQUARTERS DEPARTMENT OF TEXAS,
San Antonio, Texas, July 11, 1877.

GENERAL: I have the honor to submit the following report upon the operations conducted under my charge as chief engineer officer Department of Texas, from the date of my assignment to duty in such capacity to the close of the fiscal year ending June 30, 1877:

In obedience to Special Orders No. 237, dated Headquarters of the Army, Adjutant General's Office, November 17, 1876, I reported to the commanding general, Department of Texas, and was assigned to duty, December 11, 1876, at his headquarters, relieving First Lieut. William Hoffman, Eleventh United States Infantry, then acting engineer officer of the Department.

As there were no funds for the purpose of conducting operations of survey, or for compensation of draughtsmen, or other employés, the duties in the office consisted only of issue of maps, and in furnishing such information as the records of the office contained to persons desiring it, and in the issue of instruments, stationery, &c., to those officers who were engaged in making notes of reconnaissances or maps of those already made.

On January 4, 1877, I left department headquarters under instructions from the Secretary of War, through the Chief of Engineers, to perform certain other duties at Fort Brown, Texas, and returned by reason of instructions from the Chief of Engineers, July 2, 1877. During my absence, the ordinary routine duties of the office have been performed at various times by Maj. J. H. Taylor, assistant adjutant-general; Lieut. Col. J. S. Mason, acting assistant inspector-general of the Department; and Lieut. H. G. Brown, aide-de-camp to the commanding general.

During the summer of 1876, Lieutenant Hoffman made the tour of the several northern posts of the department for the purpose of determining their positions in latitude and longitude. For longitude, differences of time between the posts and the Lake Survey observatory at Detroit, Mich., were determined by telegraphic signals. Latitudes were determined by sextant observations.

Lieutenant Hoffman labored under many difficulties in the performance of his work, being entirely without assistance save that rendered by enlisted men at the various posts, and having chronometers which he describes as entirely unreliable. He only claims for his results that they are reliable to within the nearest second of time.

Within my knowledge no report has been made of this work. I, therefore, give tabulated below the resulting longitudes which have been left on record in this office, in order that they may be preserved. There are no records of the resulting latitudes in this office.

Longitudes, west of Greenwich, of military posts in Texas, determined from time-observations by Lieut. William Hoffman, Eleventh United States Infantry, by telegraphic signals to and from observatory of United States Lake Survey, Detroit, Mich., 1876.

	h.	m.	s.	°	′	″
Fort Richardson (new sun-dial)	6	32	38.7	98	09	31.05
Fort Griffin	6	36	55	99	13	45
Fort Stockton	6	51	30	102	52	30
Fort Concho	6	41	43	100	25	45
Fort McKavett	6	40	25.52	100	06	22.8

During my absence, on duty, from Fort Brown, Texas, in February and March, 1877, my assistant, Mr. O. S. Wilson, was, by my direction, engaged in making a careful survey of the post of Ringgold Barracks, Texas, which was required by the department commander for the purpose of adjusting the boundaries of the proposed reservation.

The survey carefully made with theodolite and chain, and with reference to the true meridian, was platted on a scale of one three-thousandths, making a map of 690 square inches. Mr. Wilson also made observations with the sextant for the latitude of the sun-dial at Ringgold Barracks, the results of which are given in tabulated form below.

Observations with sextant for latitude of sun-dial, post of Ringgold Barracks, Texas, by Assistant Engineer O. S. Wilson, March, 1877.

Date.	Object.	Number of observation.	Result.			Mean.		
1877.			°	′	″	°	′	″
March 2	Polaris	25	26	22	48.7			
7	....do	25			39.4			
7	....do	25			37.0			
8	....do	25			31.4			
8	....do	25			35.2			
						26	22	38.3
March 3	Sun	40	26	23	12.2			
7	....do	40		22	58.5			
8	do	40		22	33.7			
						26	22	54.[illegible]
Latitude of sun-dial, Ringgold Barracks						26	22	46.6

Very respectfully, your obedient servant,

JAMES F. GREGORY,
Captain of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

APPENDIX T T.

ANNUAL REPORT OF LIEUTENANT J. C. MALLERY, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1877.

EXPLORATIONS AND SURVEYS IN THE DIVISION OF THE PACIFIC.

ENGINEER OFFICE, MILITARY DIVISION OF THE PACIFIC,
San Francisco, Cal., July 5, 1877.

SIR: I have the honor to submit my annual report for the year ending June 30, 1877.

The discharge of the office employés at the close of the preceding fiscal year stopped the drawing of four important maps, which have been much needed. This will necessitate the redrawing of these maps, as other draughtsmen cannot finish them. It has been impossible to meet the frequent demand for maps.

The troops have been actively employed throughout the year, in parts of the division, in operations against the Indians.

There is at present an Indian outbreak of considerable magnitude in Idaho Territory, and there are no maps to issue to the troops who have been sent from the adjacent military department, and who are not familiar with the country.

FIELD-WORK.

The eastern boundary of the Presidio or Fort Point military reservation, as established by the act of Congress approved May 9, 1876, was surveyed and marked by stone monuments.

The boundaries of the Point San José military reservation were surveyed and marked.

In compliance with a division order, I visited the military reservation at Monterey, Cal., and made a report to the major-general commanding upon the custodianship thereof.

For several years the sand-downs west of the military post of Point San José, San Francisco Harbor, have been encroaching upon the post to such an extent as to seriously block the roads and to endanger the buildings. The method resorted to to keep off the drifting sand—that of building high fences—was of doubtful expediency and economy, as in one season the sand would cover the fence and necessitate the building of another fence above the old one. In this way the sand, in some places 30 feet above the natural surface of six years ago, had collected to the windward of the post and threatened to bury it. The sand comes partly from the beach of the reservation, but principally from the sand-downs west of the reservation which have been supplied from the beach to the windward. From April to October the wind blows in the afternoons from a direction nearly unvarying, and with a maximum velocity of about 32 miles an hour. The two objects to be attained were to cut off the supply of sand coming from outside the reservation, and to fix the sand already upon the reservation. The first object has been at-

tained by building a brush-fence along the beach and the western boundary-line. The second object has been secured by planting in the sand lupine-seed, (*Lupinus arboreus.*) This lupine shrub has a yellow flower and reaches its maximum growth in four years, when it is five or six feet high, and covers an area of about 50 square feet. It is a hardy plant, and has long tap-roots, which render it suitable for planting in sand. There are 36 acres in the sand tract of the reservation. The lupine-seed was gathered by the soldiers upon the Presidio reservation. Barley was mixed with the lupine-seed in the proportion of 3 pounds of lupine to 100 pounds of barley. This mixture was sown broadcast after the surface had been harrowed. About 200 pounds were used to the acre. The sowing was done immediately after the first rains, which occurred in October. The sand was then rolled to consolidate it. The lupine comes to the surface slowly, sending its roots down several feet before appearing above the surface. The barley was planted, as it sprouts soon. It came to the surface in ten days, and held the sand until the lupine was well rooted and had developed into vigorous plants. In spite of the exceptionally unfavorable year, the annual rain-fall having been only 11 inches, while for the preceding five years the average annual rain-fall was 24.93 inches, the barley has matured and the lupine has grown into healthy plants, preventing the drifting of the sand upon most of the sand tract. In the few places where the lupine did not grow the sand has been held in place by covering the surface with brush. Among the causes of the rapid growth, in sand-downs, of certain plants, are the looseness and warmth of the soil and the higher level of the surface of permanent moisture, due to capillary attraction. It is the intention to raise from seed, in a sheltered plantation, a number of small trees, which will be transplanted to the sand-downs when they are sufficiently vigorous. The Monterey pine and cypress trees have been selected for this purpose, because of their rapid growth in sandy soils, and their thick foliage, which breaks the wind. In this way, in a few years, a valuable growth of trees can be secured, which will shelter the post from the high summer winds and obviate the constantly recurring expenditures for wind-fences. In fact, when the sand is held in place, several plants grow spontaneously upon it. The slopes of the sand-downs are gentle to the windward and steep to the leeward. Their crests have curvilinear directions nearly normal to the direction of the prevailing winds, and move to the leeward at a considerable rate. As the sand accumulates upon the beach, it is proposed to hold it in place by planting some of the grasses, as the mat-grass, (*Psamma arenaria*,) which have proved themselves valuable for this purpose in the works of sand-reclamation upon the coasts of Europe. It is probable that this will not be necessary, as there is a vine which is growing near the beach-fence of brush. This brush-fence has been placed at about 10 feet from the extreme high-water line. The slope of the surface of the dry sand between the fence and the high-water line will be increased by the accumulation of the sand stopped by the fence. This will diminish the amount of sand moved, and will facilitate its being held in place by the sand-binding grasses.

The military reservation at Camp Thomas, Arizona, was surveyed by First Lieut. E. D. Thomas, Fifth Cavalry, A. D. C., and acting engineer officer, department of Arizona.

OFFICE-WORK.

Information for the publication of an outline description of the military posts in the Military Division of the Pacific has been collected.

Work has been commenced in making reduced drawings of the plans of the military reservations and of the posts, to accompany this publication.

A very creditable map of the Saint Joseph and Clearwater Rivers, Idaho, has been received by Lieut. Robert H. Fletcher, Twenty-first Infantry. This map was compiled by Lieutenant Fletcher from Eastwick's Survey of the Clearwater River; scouts made by Maj. J. B. Sanford, First Cavalry, 1872–'73; and from Col. J. C. Davis's route of march in 1874. Lieutenant Fletcher was topographical officer upon the military expeditions.

The State of California has sold to private parties the "tide-lands" adjoining the shore-lines of the military reservations of Point San José, the Presidio, and Peninsula Island, extending into San Francisco Bay, to a depth of water of 24 feet at extreme low tide in the first two cases, and to a depth of 9 feet in the latter case. A wharf and house have been built upon the "tide-lands" of Peninsula Island. The Government wharves at the Presidio and Point San José are on property upon which taxes are paid by persons having deeds from the State of California. If the part of San Francisco Bay between the shore-line of these two reservations and the established city water-front should be filled in, the use of the reservations would be interfered with. It is therefore important that the question of the ownership of this property should be definitely settled.

A list of reports of scouts received during the year, and a table of distances from and to different points in Arizona, compiled by Lieut. E. D. Thomas, Fifth Cavalry, acting engineer officer, department of Arizona, are appended.

The following is an abstract of the office-work, viz: Drawings, 23; tracings, 58; maps mounted, 45.

Amount desired for fiscal year ending June 30, 1879, $10,000.

Very respectfully, your obedient servant,

J. C. MALLERY,
First Lieutenant of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. Army.

Reports and maps of scouts received at Engineer Office, Military Division of the Pacific, by First Lieut. J. C. Mallery, Corps of Engineers, engineer officer, during fiscal year ending June 30, 1877.

Date of receipt.	From—	Commanding officer.	Description of scout.	Date of scout.	Miles traveled.	Filed or returned.	Report.
Aug. 12, 1876	Camp Gaston, Cal.	R. C. Parker, Captain Twelfth Infantry.	From Camp Gaston to Pine Creek and return by Arcata Trail.	July —, 1876	45	F.	Map.
Aug. 12, 1876	Camp Gaston, Cal.	G. R. Smith, Lieutenant Twelfth Infantry.	From Camp Gaston to Tinsley's Station and return.	July —, 1876	130	F.	Map.
Sept. 19, 1876	Camp Independence, Cal.	W. W. Wotherspoon, Second Lieutenant Twelfth Infantry.	From Camp Independence to head-waters of Tuolumne River, via Owens River and Mona Lake, and return via Bloody Cañon and Yosemite Valley.	Sept. 8, 1876	198	F.	Report.
Sept. 9, 1876	Camp Gaston, Cal.	James Halloran, First Lieutenant Twelfth Infantry.	From Camp Gaston to South Fork of Salmon River and return.	Sept. 4, 1876	80	F.	Map.
July 5, 1876	Camp Independence, Cal.	W. W. Wotherspoon, Second Lieutenant Twelfth Infantry.	From Camp Independence to Visalia, Cal., and return via King's River Valley, 95 miles, 50 miles of good wagon road on the west and 10 miles on the east; the rest trail.	June —, 1876	190	F.	Map.
July 5, 1876	Camp Independence, Cal.	W. W. Wotherspoon, Second Lieutenant Twelfth Infantry.	From Camp Independence to Visalia. Profile of trail and road via Kearsarge Pass and King's River.	....	....	F.	Map.
Oct. 3, 1876	Camp Bowie, Ariz.	Lieutenant Henely, Sixth Cavalry	From Camp Bowie, Ariz., to Ralston, Hatchet Mountains, &c., and return.	Aug. 30, 1876	451	R.	Report.
Oct. 31, 1876	Camp Bowie, Ariz.	Sergeant Pruo, Sixth Cavalry	From Camp Bowie, Ariz., to the Chiricahua Mountains and return.	June to July, 1876.	300	R.	Report.
Oct. 31, 1876	Camp Bowie, Ariz.	Sergeant Baker, Sixth Cavalry	From Camp Bowie, Ariz., to the Dragoon Mountains and return.	June to July, 1876.	300	R.	Report.
Oct. 31, 1876	Camp Bowie, Ariz.	Sergeant Robbins, Company H Sixth Cavalry.	From Camp Bowie, Ariz., to the Chiricahua Mountains and return.	July —, 1876	150	R.	Report.
Oct. 31, 1876	Camp Verde, Ariz.	Capt. Charles Porter	From Camp Verde, Ariz., to Tonto Basin, Ariz., and return.	Sept. 30, 1876	235	R.	Report.
Oct. 31, 1876	Camp Verde, Ariz.	Guide Sieber	From Camp Verde, Ariz., to the "Caves," on Clear Creek, Ariz., and return.	Sept. 16, 1876	150	R.	Report.
Oct. 31, 1876	Camp Verde, Ariz.	....	From Camp Verde, Ariz., to the southern boundary of Red Rock country, &c., and return.	Aug. 13, 1876	160	R.	Report.
Nov. 7, 1876	Camp Lowell, Ariz.	Captain Whiteside, Sixth Cavalry.	From Camp Lowell, Ariz., to San Pedro and Santa Cruz Valleys and return.	Oct. 1, 1876	425	R.	Report.
Nov. 21, 1876	Camp Grant, Ariz.	T. C. Tupper, Captain Sixth Cavalry.	From Camp Grant, Ariz., to Sulphur Springs, Dragoon Mountains, San Pedro River, to Mexican Boundary and Chiricahua Mountains to Camp Bowie and return.	Oct. 2, 1876	534	R.	Report.
Mar. 16, 1877	San Diego Barracks, Cal.	John Pitcher, Second Lieutenant First Cavalry.	From San Diego Barracks, Cal., to Campo, via Cajon and Pine Valleys, and return via Julian, Warner's, and the Santa Margarita River.	Jan. 30 to Feb. 8, 1877.	220	R.	Report.

Apr. 28, 1877	Camp Gaston, Cal	G. R. Smith, Lieutenant Twelfth Infantry.	From Camp Gaston and its vicinity and return	Apr. 12, 1877	60	F.	Map.
May 11, 1877	San Diego Barracks, Cal	John Pitcher, Second Lieutenant First Cavalry.	From San Diego to San Bernandino, via Tye and Jacinto Valleys, and return via Ternecula (odometer measurements.)	Apr. 10, 1877	302.55	F.	Map & report.
June 11, 1877	Camp Bidwell, Cal	J. M. Norwell, Captain Twelfth Infantry.	From Camp Bidwell to Old Camp McCarry, (Summit Lake,) Cal., via Sand Creek, Cal., Massacre Creek, Cal., Grizzly Springs, and return by Badger Flat, &c.	May 5, 1877	188	F.	Map & report.
			Total		4,118.55		

TABLE OF DISTANCES FROM AND TO DIFFERENT POINTS IN ARIZONA, COMPILED FROM RECORDS OF ENGINEER OFFICE, HEADQUARTERS DEPARTMENT OF ARIZONA, BY FIRST LIEUTENANT E. D. THOMAS, FIFTH CAVALRY, A. D. C. AND ACTING ENGINEER OFFICER.

FROM PRESCOTT, ARIZONA, TO—

Posts and stations.	Miles.	Route traveled.
Apache, Camp	215½	Via Camp Verde and Mogollon Mountains, General Crook road.
	269½	Via Camp Verde, Stoneman's Lake, Sunset Crossing, ambulance and freight road, old road.
Bowie, Camp	332	Via stage-road and Tucson.
Ehrenberg	197	Via freight-road.
	192	Via Wickenberg stage-road.
	166	Via Skull Valley and Gilson's ranch, ambulance-road.
Grant, Camp	376	Via Tucson stage and ambulance-road.
	341	Via Black Cañon and Phœnix, ambulance and freight road.
McDowell, Camp	102	Via Black Cañon.
Mojave, Camp	165	
Phœnix	143	Via Wickenberg, old road.
	98	Via Black Cañon, new road.
	114	Via new road and Skull Valley, stage and ambulance route.
	160	Heavy-freight road.
Pima Agency	151	Via stage and ambulance route.
	127	Via Black Cañon and Phœnix, ambulance-route.
Pioche, Nev	434	Via Cerbat, Mineral Park, and Saint George.
Saint George, Nev	350	
Sacramento, Cal	831	Via Dos Palms and Los Angeles.
San Bernardino, Cal	365	Via Dos Palms.
San Carlos, (Camp,) Ariz	422	Via Tucson, ambulance-route.
	269	Via McDowell and Old Camp Grant, not traveled.
San Diego, Cal	530	Via Maricopa Wells, stage and ambulance route.
San Francisco, Cal	855	Via Dos Palms and San Bernardino, ambulance-route.
San Pedro, Cal	455	Via Dos Palms and San Bernardino, ambulance-route.
San Pedro, Ariz	284	
Santa Fé, N. Mex	524	Via Sunset Crossing and Wingate.
Stockton, Cal	783	Via Dos Palms and Los Angeles.
Thomas, Camp	429	Via stage-road.
	394	Via Black Cañon.
Tucson, Ariz	248	Via stage-road.
	225	Via Black Cañon, Phœnix, and Sacaton, ambulance-route.
Union, Fort, N. Mex	624	
Verde, Camp	42½	Via Copper Cañon, ambulance and freight route.
Whipple, Fort, Ariz	1½	
Wickenberg, Ariz	87	Via old road.
	65	Via stage-road, Skull Valley, ambulance-route.
Willow Grove, Ariz	85	
Wilmington, Cal	450	Via Dos Palms and Los Angeles.
Wingate, N. Mex	286	Itinerary of Col. R. I. Dodge, Twenty-third Infantry. Odometer measurement.
Yuma, Fort, Cal	304	Via Maricopa Wells.
Zuni, N. Mex	240	Via Sunset Crossing.

FROM CAMP M'DOWELL, ARIZONA, TO—

Apache, Camp	321½	Via Camp Verde.
Bowie, Camp	232	
Colorado Indian Res	255	Stage, ambulance, and freight route.
Date Creek, (old camp)	110	Ambulance and freight route.
Ehrenberg	210	

Table of distances from and to different points in Arizona, &c.—Continued.

Posts and stations.	Miles.	Route traveled.
Florence	55	Ambulance and freight route.
Grant, Camp	243	Via Tucson.
Goodwin, (old camp)	267	Via Florence and Desert road, Tucson and Tres Alamos, upper crossing San Pedro.
Hardyville	261	Via Black Cañon and Prescott, ambulance, stage, and freight route.
Lowell, Camp	134	Ambulance and freight route.
Maricopa Wells	45	Do.
Mojave, Camp	267	Via Black Cañon and Prescott, ambulance and freight road.
Phœnix	27	Ambulance and freight route.
Prescott	102	Via Black Cañon.
	141	Via stage-route.
San Carlos	297	Via Tucson and Camp Goodwin.
Tucson	127	Via Florence and Desert Wells, ambulance and freight route.
Verde, Camp	99	Via Black Cañon, Antelope Springs, and Copper Cañon, ambulance and freight road, new route.
Whipple, Fort	100¼	Via Black Cañon, ambulance and freight route.
	142½	Stage-route.
Wickenberg	83	Stage, ambulance, and freight route.
Yuma, Fort	222	Stage, ambulance, and freight road.
Apache, to San Carlos,	65	Via trail.
	100	Via Goodwin, ambulance and freight route.
FROM SAN CARLOS, ARIZONA, TO—		
Apache, Camp	65	Trail.
Grant, Camp	100	Ambulance and freight road.
McDowell, Camp	297	Via Tucson and Camp Goodwin, ambulance and freight route.
Maricopa	284	Ambulance and freight road.
Prescott	411	Via Tucson, ambulance route.
Tucson	186	Do.
Yuma, Cal	425	Do.
Bowie, Camp	115	Do.
Mojave, Camp	587	Via Tucson stage-route; ambulance route.
Bowie, Camp, to Grant, Camp.	'45	Ambulance and freight road.
FROM TUCSON, ARIZONA, TO—		
Apache, Camp	225	Via Grant and old Camp Goodwin, ambulance and freight road.
	205	Via old Camp Goodwin.
Bowie, Camp	105	Ambulance and freight road.
Colorado, Camp	343	Via Ehrenberg, ambulance, stage, and freight route.
Ehrenberg	303	Via Wickenburg, stage-route.
Florence	72	Desert road, ambulance and freight road, stage-route.
Grant, Camp	116	Ambulance and freight road.
Hardyville	437	Via Prescott.
McDowell, Camp	127	Via Florence and Desert route, ambulance and freight road.
Lowell, Camp	7	
Maricopa Wells	98	Stage-route.
Mojave, Camp	441	
Prescott	225	Via Black Cañon.
San Carlos	186	Via Grant.
Verde, Camp	223	Via Black Cañon.
Wickenberg	176	Stage and ambulance route.
Yuma	275	Via Maricopa Wells, stage-road.

ITINERARY OF ROUTE.

FROM CAMP VERDE TO CAMP APACHE.

Camp Verde to Clear Creek	4
Clear Creek to Cedar Tanks, sign-board, wood, and grass	16
Cedar Tanks to Baker's Springs, sign-board, wood, and grass	12
Baker's Springs to General Springs, sign-board, wood, grass scarce	12
General Springs to Don Robert's Springs, sign-board, wood, grass scarce	5
Don Robert's Springs to Camp Adam, sign-board, wood, and grass	7
Camp Adam to Dead-Shot Creek, sign-board, wood, and grass scarce	9
Dead-Shot Creek to Laguna, (sign-board down,) wood, grass scarce	11
Laguna to foot of Mesa, sign-board, wood, grass scarce	9
Foot of Mesa to Phœnix Park, wood and grass	8
Phœnix Park to Water-Holes, wood and grass	20
Water-Holes to Clark's ranch, wood and grass	14
Clark's ranch to Crossing, wood and grass	15
Crossing to forks of road, wood and grass	7
Forks of road to Camp Apache	24
Total distance	173

REMARKS.

After passing the tree blaz d, and marked 59¼ from Verde, the distances are approximated, as actual measurements stop at that point. Water is generally found about 8 miles from Baker's Spring, in a creek near remains of a hut. From that point until Dead-Shot Creek is passed is the softest portion of the road. If no water is found at Camp Adam, where the creek crosses the road, it can be found down in the cañon to the left of the road. About midway between Phœnix Park and the Water-Holes there is a sign-board marked "Water" to left of the road. The Water-Holes are to the right of the road about a mile. Between Clark's ranch and Crossing, about 10 miles out, water is found in a ravine to left of road, sign-board on tree.

Data obtained from records of Engineer Office, Department of Arizona, and from actual measurements by chain and odometer.

E. D. THOMAS,
First Lieutenant Fifth Cavalry, A. D. C.,
Acting Engineer Officer, Department of Arizona.

PRESCOTT, ARIZ., *February* 17, 1877.

APPENDIX U U.

ANNUAL REPORT OF LIEUTENANT E. D. THOMAS, FIFTH CAVALRY, ACTING ENGINEER OFFICER, FOR FISCAL YEAR ENDING JUNE 30, 1877.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF ARIZONA.

ENGINEER OFFICE,
HEADQUARTERS DEPARTMENT OF ARIZONA,
Prescott, Ariz., August 30, 1877.

SIR: I have the honor to submit the following annual report of the operations of this office for fiscal year ending June 30, 1877.

Congress having made no appropriation for surveys in military divisions and departments, and no funds being available, my assistance has been limited to the services of one draughtsman, furnished from and on duty with the general-service detachment, at headquarters Department of Arizona, through the kindness of the general commanding, which has enabled me to perform the duties absolutely required and add to official map such information as was furnished by officers commanding troops in pursuit of renegade Indians.

Work has therefore been limited to the routine incidental to department headquarters, and, in the field, to a few minor surveys, and the preparation of maps of these surveys.

The survey of Camp Thomas military reservation was made in November, 1876. The reservation was declared by the President and announced in General Orders No. 14, Headquarters Department of Arizona, June 11, 1877. Map forwarded with report of the survey.

Maps have been issued to officers serving in this department, tables of distances distributed to post-commanders, and tracings made.

This office has not yet received the fourth sheet of map of Department of Arizona; consequently, no complete official map could be furnished. Constant inquiries are made, and repeated requests by letters sent, to this office by officers serving in this department, for completed maps; and I have been unable to comply with their requests, and invariably replied that a complete map would soon be issued, as it was in the office of the Chief of Engineers, at Washington, D. C.

SCOUTS.

I herewith submit outline map of Southern Arizona, showing movements of troops in pursuit of hostile and renegade Indians since date of last annual report. This map is based upon the official records and condensed information furnished by officers in command of the different detachments.

May 28, 1876, General Kautz, commanding department, accompanied by Colonel Martin, A. A. G., and Lieutenant Whitney, A. D. C., left Prescott and proceeded by stage to Tucson, and from thence to Camp

Bowie, Arizona, and took immediate command of the cavalry and infantry column there concentrated to operate in the removal of the then supposed formidable and warlike Chi-ri-ca-hua band of Southern Apaches.

The disposition of troops and the admirable precautions taken rendered an outbreak impossible, and the Chi-ri-ca-hua band was removed to the San Carlos Indian reservation without difficulty; a few who escaped to the mountains were pursued by troops and forced to return to their reservation or flee for protection to Indian agencies in New Mexico.

The marches and routes traveled by the troops under Colonel Oakes, Sixth Cavalry; Major Compton, Sixth Cavalry; and Captain Brayton, Eighth Infantry, who commanded detachments or mixed commands under General Kautz, are given upon the map inclosed, viz:

Headquarters Sixth Cavalry, Companies B, F, and K, Sixth Cavalry, under command of Colonel Oakes, from the 2d of June, 1876, to 18th of June, 1876, from Camp Lowell to Camp Bowie, and returned to Camp Lowell.

Battalion of Sixth Cavalry, consisting of C, G, I, and M, and Company A, Indian scouts, under command of Major Compton, left Camp Grant June 3, and scouted through San Simon Valley, returning to Camp Grant June 18, 1876.

April 16 to July 3, 1876, Capt. G. M. Brayton, with Companies B and E, Sixth Cavalry, and B, Indian scouts, scouted from Camp Verde through Tonto Basin, Pinal Mountains, San Pedro, and San Simon Valleys, Chiricahua Mountains, and return to Camp Verde.

August 13 to August 29, 1876, Captain Charles Porter, Eighth Infantry, with detachment of Sixth Cavalry and Company B, Indian scouts, scouted through Red Rock country from Camp Verde, killing 7 Indians and capturing 7 prisoners.

August 30 to September 21, Lieutenant Austin Henely, Sixth Cavalry, with Company H, Sixth Cavalry, scouted Chiricahua Mountains, portions of New Mexico, and Sonora. From Camp Bowie, September 28 to October 26, 1876, Captain Whitside, with Company B, Sixth Cavalry, scouted San Pedro, Sonoita, and Barbacomba Valleys from Camp Lowell.

October 8 to November 2, 1876, Captain Tupper, with Company G, Sixth Cavalry, scouted San Pedro and Gila Valleys from Camp Grant.

December 11 to January 12, Lieutenant Rucker, with detachments of H, L, Sixth Cavalry, and C Company Indian scouts, scouted country in vicinity of Steen's Peak range of mountains, thence to the Ludendorf Mountains, about 40 miles south of Ralston, N. Mex., where he (Lieutenant Rucker) had an engagement with hostile Indians, killing a number and capturing many prisoners, destroying a large amount of their property.

February 11 to March 11, 1877, Lieutenant Rucker, with Company H, Sixth Cavalry, and C, Indian Scouts, scouted Gila and Burro Mountains from Camp Bowie.

March 3, Maj. F. D. Ogilby made a trip from Camp Apache to Globe City, Arizona, Lieutenant Baird, Sixth Cavalry, furnishing topographical sketch of same, calling attention to the false position of Apache Mountains upon official maps; his statement was indorsed by Major Ogilby and forwarded.

I have made the corrections upon inclosed map, and will do so upon official map.

Lieutenant Craig, Sixth Cavalry, with detachment Company B and

M, Sixth Cavalry, scouted Huachuca Mountains, vicinity of San Rafael and Santa Cruz, Sonora, and Sonoita Valleys, from April 18 to April 21, 1877.

June 5 to June 24, Lieutenant Hanna, with detachment B and M, Sixth Cavalry, and Indian scouts, scouted country in vicinity of old Camp Crittenden, Wallen, Santa Cruz and Barbacomba Valleys from Camp in Huachuca Mountains.

All routes and trails are shown on accompanying map.

MILITARY ROADS.

The Skull Valley and Prescott wagon-road was completed November 6, 1875, and opened for travel immediately after; it was repaired the following summer as much as practicable with the unexpended balance of the appropriation. This road, which runs over Sierra Prieta range of mountains, is very liable to damage from washes from winter rains and snow-storms, and needs yearly repairs to keep it in good order and proper condition for travel. A small appropriation is respectfully asked for this purpose. Map and estimates submitted with report.

Prescott and Camp McDowell road, with branch to Camp Verde, was completed February 29, 1876, and needs repair. Map and estimates are also submitted for this road.

I transmit, herewith, map and estimate of cost of repair of military road between Camp Verde and Sunset Crossing, Department of Arizona, and beg to call attention of the Chief of Engineers to the urgent and imperative necessity of securing, if possible, an appropriation from Congress for the repair and substantial improvement of this important interior line of communication between Arizona, New Mexico, and the Eastern States. The importance of rendering this a good and easily-traveled freight and stage route will be readily perceived upon an examination of the ordinary topographical maps of Northeastern Arizona and New Mexico, and the calculation of distances of lines of travel from railroad centers in Colorado and New Mexico to posts in Arizona, as compared by lines of travel and ordinary routes of communication from eastern cities via San Francisco to posts in Arizona.

The completion of the Denver and Rio Grande Railroad to Fort Garland, New Mexico, and the feasibility of a good wagon-road from Fort Garland to Fort Wingate, New Mexico, and thence to Prescott—department headquarters—and northern posts, will materially reduce the cost of transportation, and increase the comfort of troops in Arizona, by being supplied from markets of Chicago and Saint Louis, far preferable to San Francisco, excepting one item, "canned fruit." It will also reduce the price of transportation of Army supplies, an important question now, when appropriations are reduced to the lowest possible limit; while it also increases the facilities of mail-communications and travel to and from the Eastern States. Officers and men under orders for eastern stations can, by the opening of this route, reach the terminus of the railroad in New Mexico in about the same time that it now takes to arrive at the terminus of the Southern Pacific Railroad, thus avoiding delays, snow-blockades, wash-outs, spring floods, additional expenses, and the annoyances and discomforts of traveling through a State where national-bank notes are not accepted as the legal-tender and circulating medium of its citizens and transient inhabitants.

In the winter months frequent and long delays occur in the arrival of eastern mails, due to snow-blockades on the Union and Central Pacific Railroads, a source of extreme annoyance to troops mainly from the Eastern States stationed in Arizona, who depend almost entirely upon the clothing-markets in the east for wearing-apparel, and receive all

goods by mail, rely upon regular transmission of periodicals, and who have no interest in common with the people of the Pacific slope.

Some dissatisfaction has existed, and complaints have been made, about the irregularity of mails, when eastern mails were forwarded by Santa Fé, N. Mex. This was caused through the condition of the road, rendering it impracticable to transport mails over the Mogollan Mountains, except on horseback, a distance of 60 miles. This will be obviated after repair of road, by the placing upon the route a regular line of passenger-coaches, insuring rapidity, regularity, and reliability in the transmission of mail-matter upon this, a shorter, less expensive, and more direct road to headquarters Department of Arizona, Prescott, the capital, and military posts in the eastern part of Territory.

The unexampled prosperity of Arizona, the extraordinary development of its mineral resources, and the large immigration to this section of country demand a short and inexpensive route to the Eastern States for commerce, accommodation of officers, citizens, and soldiers living and serving within its borders.

During the last season the grangers of Arizona did not grow sufficient wheat to supply the demand for flour for Army or civil use, necessitating heavy and numerous shipments of flour from New Mexico by contractors and merchants to fill contracts or to supply their local markets; additional charges for freight were made to cover detours and almost impassable nature of roads, consequent increase of price of flour, which would have been avoided by keeping the road in proper repair.

The extensive Mormon and other settlements upon the Little Colorado, the facilities for cultivating, raising, and bringing into the markets millions of pounds of wheat, barley, and corn annually through the medium of this road, will considerably reduce the expenses of maintaining troops in this department.

The road was projected and completed by military labor under the supervision of an Army officer under General Stoneman's administration of affairs pertaining to this department, finished and opened for travel November 30, 1870, and shortens distance to Sunset Crossing about 60 miles; it is built over Mogollan Mountains, through dense forests of pine and cedar, a road well watered, excellent grazing, short and convenient drives. The road has never been repaired or improved in any way since its opening, and running over rocky mesas and malpays country for 20 miles is in its present condition impassable for either light or heavy teams.

For consideration of proper authority special rates are herewith submitted, furnished by general freight agent of Kansas-Pacific Railways, for freights from New York, Chicago, Saint Louis, &c.

		100 pounds.
From New York	first class	$4 27
	second class	3 63
	third class	2 99
	fourth class	2 31
From Chicago	first class	3 52
	second class	2 73
	third class	2 29
	fourth class	1 86
From Saint Louis	first class	3 32
	second class	2 73
	third class	2 29
	fourth class	1 81
From Kansas City or Leavenworth	first class	1 50
	second class	1 50
	third class	1 50
	fourth class	1 25

These rates are from places above mentioned to Fort Garland, Colorado, the present terminus of railroad. From there the rates to Prescott, Ariz., will be $5.70 per 100 pounds for the entire distance.

Freight will be delivered in thirty days after reaching end of railroad, by mule teams. By examination of rates above enumerated, and estimating cost of shipments from the East through San Francisco to posts in this department, it will be seen that there will be a great saving of cost in transportation of supplies for Army consumption, besides a more expeditious method of delivery, thereby ignoring that "terrible," sordid, and unscrupulous monopoly, the Southern Pacific Railroad.

The expenditure of the amount estimated for, will be a wise and beneficent measure, calculated to improve the condition of the Territory, benefiting both citizens and military, and bringing yearly into the Treasury of the United States millions of money, which now lies dormant for want of development.

Under provision of General Order No. 62, current series, Headquarters of the Army, I have now on duty in the engineer office two competent draughtsmen, who will be of great service to me, and through whom it is hoped to have much valuable information incorporated in maps.

An office map of the department will be commenced immediately, and work upon it continued till it is finished.

I have been on duty as acting engineer officer of the department for over two years, and have not received any of engineer appropriation, although I have made requests; therefore I respectfully ask that the following estimates be filled, if possible, and money sent to me as soon as it is available.

With my present assistants accurate maps can be furnished from this department as well as from any other department. Maps can be photographed, mounted, and sent to officers serving in department.

I have quite a number of plats of surveys, which were made while I have had charge of this office, and I desire copies so they can be sent to post commanders.

Estimate of funds for fiscal year ending June 30, 1878.

For the purchase of drawing-instruments, drawing-paper, inks, colors, &c..	$800 00
For chemicals and tools to photograph maps	700 00
For the purchase of odometers, prismatic compasses, and the repair of instruments	1,000 00
For office expenses	800 00
To cover expenses for tracing of township plats at the different land-offices of entire territory required for official map	2,000 00
For the purchase of sextants, chronometers, aneroids, hypsometrical apparatus, and other instruments for field astronomical observations and reconnaissances	4,000 00
Total	9,300 00

The instruments furnished this office, and now in use, are wholly inadequate, limited to two transits of old construction, and greatly in need of repairs, a level with rod and target, and two chains of the most inferior pattern; they exclude any attempt to work on a more extensive scale.

The mountainous character of the country renders the determinations of relative altitudes imperative for the correct representation of topographical features, and no instruments for this purpose are available, save the time-consuming level.

In the way of field astronomical observations, nothing has been done for want of proper instruments, tables, &c.

For office work circumstances are the same, only the deficiency of tools is here more severely felt; a few dividers and untrue triangles are the means, necessitating corresponding results.

It is two years since this office received some drawing-paper and other materials. This supply being exhausted some time ago, I am compelled to draw largely on the kindness of Captain Simpson, assistant depot quartermaster at Fort Whipple, for office-material absolutely necessary for the routine of this office.

Very respectfully, your obedient servant,

E. D. THOMAS,

First Lieut. Fifth Cavalry, A. D. C., Acting Engineer Officer.

Brig. Gen. A. A. HUMPHREYS,

Chief of Engineers U. S. A.

(Through the chief engineer Military Division of the Pacific.)

Estimate of funds required for the improvement and repair of military road from Prescott to Skull Valley, Arizona.

For construction of drains, ditches, and stone culverts	$2,400 00
For improvement of road-bed, filling and reduction of grade	2,000 00
For repair of retaining-walls, construction of railings, and repair of curves	1,600 00
	6,000 00

Estimate of funds required for the repair of military roads connecting Prescott, Camp Verde, and Camp McDowell, Arizona.

For the repair and the construction of additional drains, ditches, and culverts, the improvement and repair of water-crossings	$3,000 00
For the repair of road-covering, removal of rocks, and the construction of one retaining-wall	3,000 00
	6,000 00

Estimates for repairs and improvements upon military road, Department of Arizona, from Camp Verde, Arizona, to Sunset Crossing, Arizona.

For grading, clearing brush, cutting and making new road-bed between Camp Verde, via Wales Arnold's, to its intersection with Stoneman road, 12 miles, at $500 per mile	$6,000 00
For blasting, removal of rocks, and improvement of old road-bed, the construction of stone culverts, drains, ditches, &c., grades from intersection of new road via Wales Arnold's ranch to the Stoneman road, to Stoneman's Lake, 15 miles, at $200 per mile	3,000 00
For filling and grading, removal of rocks, and improvement of road from Stoneman's Lake to Jarvis Pass, 30 miles, at $100 per mile	3,000 00
For removal of rocks and improving grades, cuts, making of bridges from Jarvis Pass to Sunset Crossing, 25 miles, at $50 per mile	1,250 00
Total	13,250 00

The road as it now stands runs from Camp Verde up west bank of Verde River, to a point about 7 miles from the camp, and thence follows a general eastern course to Sunset Crossing.

A distance of 7 miles can be saved by running road up Beaver Creek, touching Wales Arnold's ranch (see red line on map) and on to its intersection with Stoneman road.

This cut-off will make the road more convenient to travelers, allow a better gradient, and avoid a considerable stretch of mal-pays country at the head of Beaver Creek.

The road connecting Camp Verde and Fort Whipple runs through Copper Cañon and on a general western course from Camp Verde.

E. D. THOMAS,
First Lieut. Fifth Cavalry, A. D. C., Acting Engineer Officer Department of Arizona.

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